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Ecosystem Conceptual Models
for Victorian Ecosystems

Andrea K. White

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Ecosystem conceptual models for Victorian ecosystems

Andrea K. White



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EXECUTIVE SUMMARY

This report presents ecosystem conceptual models for seven of the nine Natural Ecosystems that occur across Victoria (Dry Forest and Woodland, Wet Forest and Rainforest, Grasslands, Heathlands, Mallee, Alps and Inland Waters and Wetlands), and the terrestrial component of the Coastal Ecosystem. For each of these ecosystems the conceptual models identify values, threats, processes and drivers of ecosystem health, as well as potential management responses/interventions. We aim for the models to capture current knowledge, to be comprehensive, and to gather and consolidate information. The end result can be used to present contemporary understanding to managers and stakeholders as a means of decision support and communication, in a manner that is transparent, understandable and explicit.

Natural systems are complex, with many interacting components and many potential responses to management actions. It is difficult for individuals to conceptualise these systems, and therefore to make decisions regarding their management. In addition to this, the information required to make informed decisions about ecosystem management is commonly fragmented and diffuse. Ecosystem models have the potential to bring this information and knowledge together as an integrated whole, identifying threats to the biological values of the parks, the causal structure of ecosystems and the likely outcomes of specific management interventions. They will also promote understanding and support communication within Parks Victoria and with external stakeholders, by providing a transparent way to communicate the rationale behind management actions.

Addressing objectives associated with the management of natural systems cannot be restricted by incomplete or biased empirical information (McNay *et al* 2006). Decisions about management will be made by managers even when faced with uncertainty and incomplete information. The aim of this report was to investigate methods for using the information available to make clear, explainable management decisions, and identify areas for further research. Conceptual models are a simplified way of expressing what we know about a complex system. They make explicit links between threats/stressors (or management actions) and an ecological response, they inform the risk assessment process and are an integral component of adaptive management.

The models presented in this document will evolve over time. Model interrogation and evaluation should be ongoing, and feedback should be sought from a diverse group of people, including Parks Victoria staff, researchers, experts from other agencies (*e.g.* Department of Sustainability and Environment, Catchment Management Authorities, Department of Primary Industries, etc), land managers, field naturalists and friends groups.

The models should be continuously improved and refined as information is fed back. Currently they are based on a relatively small initial knowledge base, and should be modified as new information is sourced and incorporated. Because of this, the models do not yet fulfill the role of a comprehensive summary of knowledge, as the published literature for many of the ecosystems has only just been touched on, due to time constraints. Further investigations of the literature and input from researchers/CMAAs/DSE/PV regional and on-ground staff would significantly improve the models. The models will also need to be adapted to local conditions, to test whether all of the model components are applicable, and whether any important components and/or interactions have been omitted.

The Natural Ecosystems used here were derived by amalgamating broadly similar EVCs, based on, but not identical to those outlined in Victoria's Biodiversity Strategy (DNRE 1997). Where the Natural Ecosystems needed to be split into sub-ecosystems the Ecological Vegetation Divisions (EVDs) developed by Long *et al* (2003) were used as a guide. A sub-ecosystem may correspond to a single EVD or a group of EVDs that have been amalgamated. The Dry Forest and Woodland Natural Ecosystem covers a large part of Victoria, and has 10 constituent EVDs. In this case the Natural Ecosystem needed to be split into smaller units, each unit having common drivers, threats and management responses. Four sub-ecosystems were created. Semi-arid Woodland (EVD22) and Box-Ironbark Forest (EVD24) are logical groupings when considering the main drivers (fire regime, climate, soil etc). However, there are eight other EVDs in this Natural Ecosystem, and these have been split into Mixed Dry Forest (EVD3, 7, 8, 9, 17 and 18) and Plains Woodland (EVD19 and 23). The constituent EVDs in these latter two sub-ecosystems differ somewhat in their drivers (*e.g.* tolerable fire intervals) and will need to be reviewed. There may well be groupings that make more sense from the point of view of the values we are trying to protect and the ecosystem drivers, threats and potential management responses.

Finally, an important consideration in the management of ecosystems is the condition/state of habitat components and identified assets (or ecosystem values). Societal and personal values cannot be separated from measures of condition/state for natural systems (Borsuk *et al* 2003). The modelling methods used in this project could be used to incorporate these values by developing decision criteria that is values based rather than belief based, thus characterizing societal desires rather than behaviour of the natural system. These values, which would be reflected in the preferred state of key variables, can be elicited from stakeholders (the 'desired state' that forms the basis of management objectives). Related issues that require elicitation are what values managers should be trying to protect and what the management objectives should include. This would convert the conceptual models into decision models, and forms the basis of the next stage in model development.

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1. INTRODUCTION

This report presents ecosystem conceptual models for seven of the nine natural ecosystems that occur across Victoria. For each of these systems the conceptual models identify values, threats, processes and drivers of ecosystem health, as well as potential management responses/ interventions. We aim for the models to capture current knowledge, to be comprehensive, and to gather and consolidate information. The end result will be used to present contemporary understanding to managers and stakeholders as a means of decision support and communication, in a manner that is transparent, understandable and explicit. The models will also help to build consensus, and where this is not possible, represent areas of disagreement.

Ecological interactions are complex and conservation management problems are typically ill-defined and poorly structured. The complexity of natural systems do not lend themselves to structuring and formulation by elaborate quantitative models, or simple intuitive problem solving. Rather, making sense of these situations necessitates considering, and often times negotiating, alternative models of the ill-structured situation. Graphical capture of individual and collective narratives of cause and effect assist problem formulation by facilitating the sharing of alternative perspectives and working towards a collective perspective (Massey and Wallace 1996).

Conceptual models are able to formally represent a summary of expert understanding about ecosystems, and can be used to identify and prioritize specific information needs associated ecosystem management. In this way conceptual models form the foundation for an integrated and holistic approach to management and research. They also demonstrate how different ecosystem components interact, and how different conservation and management programs overlap and relate to each other. The models will be useful as a visualization tool, will help to get a fuller picture of each system, to think through influences and likely consequences and outcomes, and highlight the complexities that must be considered when managing natural systems, including management options and the different states that are possible.

Parks Victoria has several programs which will benefit from the development of ecosystem conceptual models, including Levels of Protection (LoP), which aims to identify priorities for management and the Signs of Healthy Parks program (SHP), which aims to assess performance of that management. Both programs need ways of identifying what the main values, threats and emerging issues are in these systems and the efficacy of management activities, while ensuring that different programs are consistent with one another. In addition, there are will be benefits to the development of Parks Victoria's Environmental Management Framework (EMF). The EMF was developed to align NVM program delivery to the adaptive

management cycle and management planning. Part of this process is to identify ecosystem threats and values and undertake the early steps in the risk assessment process (problem formulation, conceptual modelling and hazard assessment).

The ecosystem models will also provide useful input to the development of park management plans. Each park will typically have a number of different ecosystems; the ecosystem conceptual models (when fully developed) will help to quickly identify the likely threats, values, processes and important ecosystem drivers. Ecosystem models will help to identify the things on the list of potential threats, values and monitoring targets that should be followed up, making the full list more manageable. From this we could identify the most important threats, values and indicators, look at the park management plan, and align efforts with resources that are available. This approach would help to decide on the amount of effort and resources that should be assigned to different threats and values, and what should be monitored to gauge management effectiveness. This approach is in line with the EMF, which aims to manage natural values in a systematic way, taking into account limited knowledge of systems using a risk management approach. The ecosystem models would be conceptual rather than spatially explicit, and therefore able to be applied at a number of scales. This will be an advantage if objective setting could occur at state-wide scale, and the process could then be scaled down to the park level, as part of management planning.

Conceptual models will be instructive from the point of view of identifying the most important parts of any process by noting which of the elements in the model are most heavily linked, these being the most important processes, threats and management alternatives. This should help to determine if the right indicators have been chosen; *i.e.* is the program targeting the most important values/threats/drivers as identified from the conceptual models, which reflect our understanding and knowledge of the system?

Ecosystem conceptual models will be useful in communicating the strategy behind monitoring and management programs to on-ground staff, whose involvement is crucial in carrying out management actions and monitoring. Specifically, ecosystem models would help to communicate why we would monitor specific values and not others, and why we would manage specific threats and not others, by making transparent the method and approach of the prioritization process. They will be useful in conveying ecosystem understanding to new staff and in passing on knowledge when staff leave a particular park (reducing the impact of staff turnover). The models will be particularly useful for communicating with external agencies and for making funding cases internally (*e.g.* to justify expenditure).

1.1. Objectives

The development of these models will assist Parks Victoria with key management questions: what to manage (prioritizing threats), what to monitor and what research to do. The conceptual models will provide a transparent means with which to communicate the values, threats and drivers in the ecosystem types, make explicit what it is we aim to protect. It is a method which can be used to convey to staff and other stakeholders of how monitoring is targeting various ecosystem processes, threats and the impacts of management actions. The aims of the conceptual model project are to reflect basic understanding of how each ecosystem works, as a basis to:

- Promote understanding and consensus and also to identify areas of disagreement/division;
- Support decision making: to help make sensible decisions about how to manage ecosystems;
- Facilitate communication internally and externally, both to transfer our knowledge of how the system works and to communicate the rationale behind management actions;
- Identify the elements of the system to monitor to evaluate management; and
- Identify important knowledge gaps and areas of uncertainty to guide research.

The objectives of this report are:

- To gather information necessary to describe Victorian ecosystems, including the values to be protected, threatening processes and potential management interventions; and
- The production of a Concept Map and Causal Model for each ecosystem type.

1.2. Natural Ecosystems & Ecological Vegetation Divisions

Victoria has nine broad Natural Ecosystems (Figure 1.1), these are based on, but not identical to those outlined in Victoria's Biodiversity Strategy (DNRE 1997). These groupings were derived by amalgamating broadly similar EVCs, and are made up by the following groups: Alps; Coastal (including intertidal, shores and estuaries); Marine (including subtidal reefs, seagrass, soft sediments and pelagic); Dry forests and woodlands; Heathlands; Inland waters and wetlands; Mallee; and Wet forest and rainforest. The marine and coastal ecosystem groups are not included in this current program, and will be completed in subsequent work.

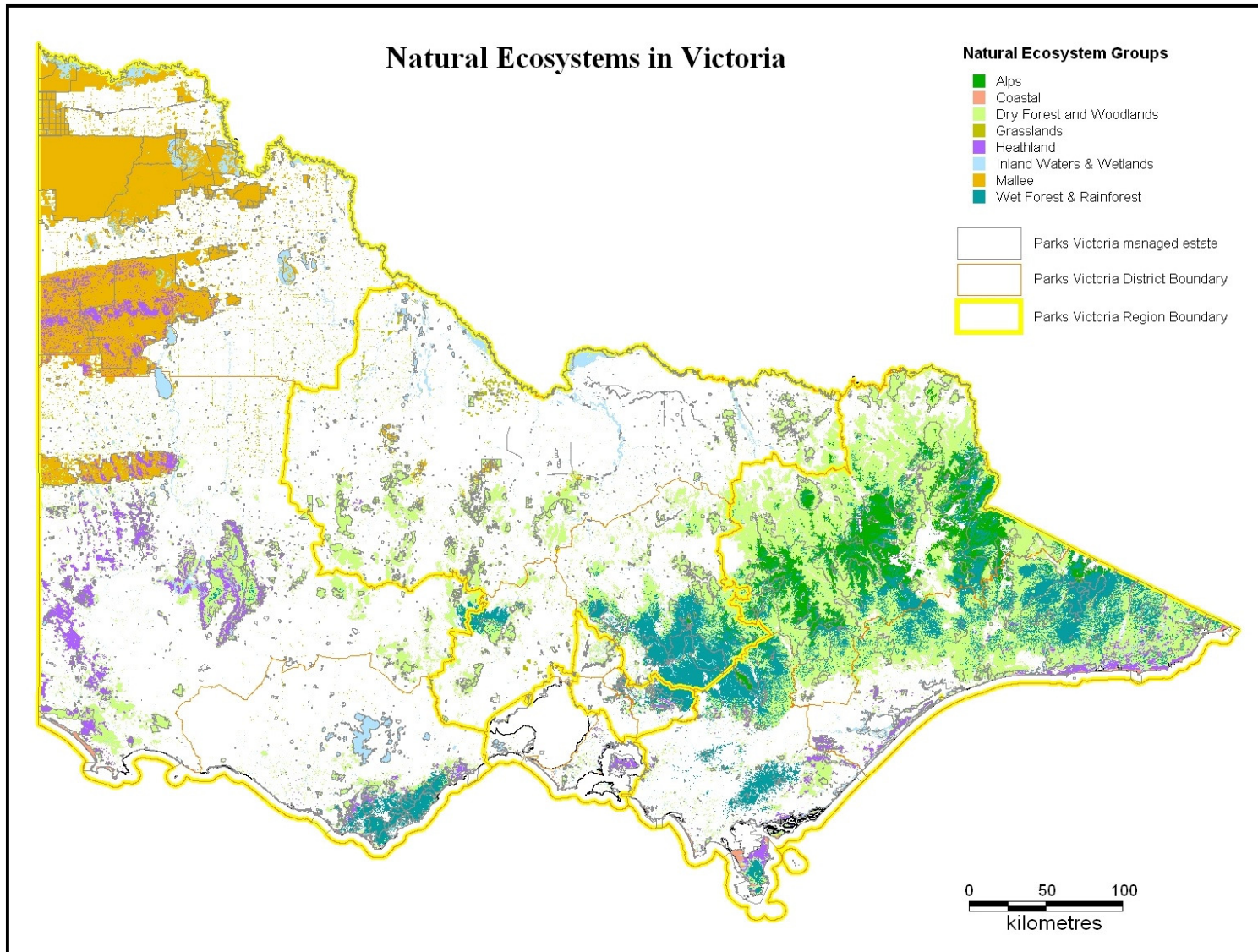


Figure 1.1: Natural ecosystem groups in Victoria derived by amalgamating broadly similar EVCs.

Where the Natural Ecosystems needed to be split into sub-ecosystems the Ecological Vegetation Divisions (EVDs) developed by Long *et al* (2003) were used as a guide. A sub-ecosystem may correspond to a single EVD or a group of EVDs that have been amalgamated. The EVDs that are included in each ecosystem model are specified. For example, a new sub-ecosystem was created called Damp and Wet Sclerophyll Forest, and is an amalgamation of EDV 10 Moist Forest and EVD 12 Tall Mist Forest (this is one of two ecosystems that come under the Wet Forest & Rainforest Natural Ecosystem).

1.3. Drivers & Scale

There is no single natural scale at which ecological patterns should be characterised (Levin 1992). This project focuses on the meso- or topo-scale (a few hundreds of kilometres). At this scale the main drivers are climate, rock type and topography, which together determine variations in nutrient availability and hydrology. For the broad natural ecosystems considered here, environmental (*e.g.* soil properties, slope, landscape position) and climatic characteristics have produced recognizable and characteristic vegetation communities. A plant community is a basic unit for vegetation mapping and management, it is a relatively homogeneous plant assemblage that occurs in a specific place/time, and can be defined at a scale relevant to a land manager. The range of plant communities in an area are observable and measurable and can be linked to the processes that embody the remaining components of the system. In this project the main terrestrial and aquatic ecosystem types are defined by the dominant structural vegetation type present. The coarse resolution of this typology implicitly assumes that management decisions are more or less insensitive to consideration of more detailed biotic entities. Although a practical starting point for managers and planners, this assumption is unlikely to be reasonable in all circumstances. Generalisations should be carefully assessed for each ecosystem (and possible sub-systems within each ecosystem).

At a finer scale (finer than considered here) micro-habitats determine where individual organisms are distributed, and we generally know more about processes at this scale. One of the largest challenges in land management is finding ways of drawing together the detailed site-specific information and data, and applying them across larger regions (Bestelmeyer *et al* 2003). This hinges on being able to generalize about the importance of particular processes in different ecological site types and at different scales. In some cases we find that the same types of processes are used to explain transitions (changes in state or condition) in similar ecological sites. For example, conditions in lowland sites may be influenced by changes in hydrology, surface soil structure and chemistry in relation to soil infiltration; in highlands the main influences may be erosion and loss of soil fertility (Bestelmeyer *et al* 2003). The important factor is that some subset of common processes in

various combinations seem to explain vegetation dynamics within different ecosystem types, and the transitions that may occur.

As mentioned above, some Natural Ecosystems have been subdivided to create sub-ecosystems. For example, the Dry Forests and Woodlands Natural Ecosystem contains four sub-systems: box-ironbark forests, semi-arid woodlands, southern lowlands forest and mixed dry forest. While a very broad model might cover all these forest and woodland types, a model which focuses on these sub-ecosystems and their specific values and issues will have greater inferential capacity and may therefore be more useful.

2. ECOLOGICAL MODELS

Ecological models are used to examine, compare and contrast hypotheses that can explain observed patterns in natural systems. An individual model that is coherent and consistent with observations can be thought of as a formal hypothesis of system dynamics (Neuhauser 2001). Statistical modelling tools in ecology have traditionally been based on frequentist methods (Pollino *et al* 2007). These have been used explain patterns in ecological systems where causes are single and separable, and discrimination can be provided using pair-wise hypotheses and a simple yes or no answer (Holling and Allen 2002). However, causes in ecological systems are likely to be multiple, overlapping (Holling and Allen 2002), and data are usually sparse.

Natural systems may be exceedingly complex, with many interacting components and many potential outcomes from management actions. It is difficult for managers and individual domain experts to conceptualise these systems, and therefore to make decisions regarding their management. Models of these systems may also be large and complex. However, diagrammatical network-based models are modular, which allows the full model to be separated into smaller, more manageable parts which can be developed separately and then re-aggregated (Pearl 2000). These models will help to identify threats and decision alternatives, determine the likely outcomes from specific management interventions and how components of the system are likely to interact.

Predicting ecosystem behaviour is inherently uncertain, and knowledge of these systems will always be incomplete. In addition, the system itself is dynamic and evolving due to management interventions and other anthropogenic impacts (Walters and Holling 1990). Levins (1966) proposed an approach whereby models are used to simplify in a way that 'preserves the essential features of the problem'. He pointed out that all models leave out a lot of information and that they are false, incomplete and inadequate. Levins (1966) suggested precision could be sacrificed for realism and generality using flexible (often

graphical) models, that assume that relationships are increasing or decreasing, convex or concave or greater than or less than a particular value, instead of specifying the mathematical form of an equation.

Ecosystems occur at scales that are not generally amenable to manipulative experiments, and the uncertainty associated with extrapolation from smaller scale experiments is difficult to quantify (Stow *et al* 2003). However, management actions can act as large-scale experiments and will enhance what is learnt through further research (Stow *et al* 2003). Using this approach, termed adaptive management, the consequences of management are monitored so that management effectiveness can be gauged and actions can be modified in response to feedback. Adaptive management requires the development of conceptual models that can outline the likely consequences of management interventions, and the important threats and processes that may be involved.

Literature reviews (a written synthesis of the research literature) are by far the most common approach used in evidence-based decision-making. However, it's unlikely to be the best approach. The complexity of interactions, the varying scale involved in individual studies, and the speculative narratives of cause and effect linking management actions to outcomes all conspire against the reader's ability to form a coherent understanding. Graphical models provide a more effective approach. Axelrod (1976) contended that "when a cognitive map is pictured in graph form it is then relatively easy to see how each of the concepts and causal relationships relate to each other, and to see the overall structure of the whole set of portrayed assertions". de Bruin *et al* (2009) tested understanding of medical risks among study participants that were provided communication materials based on written scenarios or graphical models. Graphic representations substantially outperformed scenarios in improving people's understanding of risks.

Causal models (also known as influence diagrams) are a type of network-based model that is used to represent the domain knowledge of experts (Nadkarni and Shenoy 2001); they express the judgement that certain events or actions will lead to particular outcomes. The components of a causal model are the factors that influence the system being modelled (nodes) and the causal relationships between the nodes (arcs or arrows). The direction of the arrows imply causality. Most people are able to express their understanding of a system in this manner (Cain 2001). Individuals reason by accumulating possibly significant pieces of information and organising them in relation to each other, and combining them in order to make conclusions and decisions. We use such processes to put cause and effect events into series (or networks), and use them to predict the future course of events (Nadkarni and Shenoy 2001).

Network based models, such as causal models, represent knowledge more descriptively than other types of models (e.g. regression analysis) and because of this they are particularly useful in decision analysis (Nadkarni and Shenoy 2001). They have been used extensively in policy analysis (Axelrod 1976) and management sciences (e.g. Klein and Cooper 1982) to represent factors that influence decision making. Causal models describe different domains of knowledge but also identify how they are linked; they are used in the formulation of problems and hypotheses, and to explore the potential effects of management decisions (Eden 2004).

Casual models are well suited to ecological problems, where knowledge is often imprecise, there may be diverse understandings of causality and the impacts of intervention, and very often a need to develop a common understanding amongst stakeholders (Hobbs *et al* 2002). These models can be used to promote communication and understanding between participatory stakeholders or experts, and to simulate different management scenarios to determine an optimal set of management actions. Different perceptions of causality may be revealed, providing an opportunity for learning and consensus to occur. They can also form an accessible knowledge repository and a medium for communication (Mingers and Rosenhead 2004).

2.1. Indicators

For ecological models to be useful in decision support they must provide a predictive link between management actions and ecosystem response; in addition to this the decision support tool will be more effective if the ecosystem response is represented by an attribute that stakeholders care about (Reckhow 1999, Borsuk *et al* 2004). Suter (1993) lists three desirable attributes of an indicator: (a) ecological importance, (b) social relevance, and (c) ease of measurement. Trade-offs among these three attributes are typically required. The example used by Borsuk *et al* (2004) involved process-based biophysical models that allow the prediction of water quality characteristics, such as dissolved oxygen concentration, at a fine spatial and temporal scale. While these variables are useful indicators of water quality and are easily measured, they have little meaning to decision-makers and the general public, who are likely to be more interested in things such as harmful algal blooms and fish kills.

The variables in a model that are targeted for monitoring should be good indicators of broader ecological condition. Thresholds of probable concern can be used, described by a range of spatially and temporally bounded indicators of the system's response to the main potential agents of change (Rogers and Biggs 1999). An operational definition of the desired system condition that reflects scientific rigour and broader societal value systems are

needed. These thresholds can be monitored and represent statements or hypotheses of the limits of acceptable change in ecosystem structure, function and composition.

Management goals rely on subjective judgements, *i.e.* a statement that indicates the preferred state of specific attributes of a system, over possible alternative states of these attributes (Lackey 2001). These are not inherent properties of the system, but values-laden judgements that may reflect individual, organizational and/or societal aspirations (Meyer 1997). There are many competing opinions on what these preferred or desired states should be, and therefore the input for these judgements would ideally come from a diverse group of stakeholders, and be used to guide management interventions, as a part of an active management and monitoring program.

Attributes used to gauge the condition of vegetation communities can include considerations of the cover, distribution and abundance of indigenous and introduced flora and fauna, plant structural diversity, soil structure and stability, productivity, and self-sustaining ecosystem processes. Soil stability is estimated using the amount of bare ground, litter cover, vegetation cover, the resistance of the soil surface to erosion, compaction, water flow patterns and erosional structures (*e.g.* McIntyre and Tongway 2005, Pellant *et al* 2005). A natural system that is self-sustaining has natural cycles intact, this includes nutrient cycling, hydrology (including low levels of soil compaction and erosion and high infiltration), seed supplies, floristic and structural diversity at a variety of scales (Eddy 2002). Individual species mortality and reproductive success should also be considered.

Indigenous plant community composition and distribution (including consideration of important functional and structural groups), is usually related to the theorised pre-settlement or historic state. For example, the proposed pre-disturbance state for grasslands would be no weeds and high diversity and cover of native species (Prober and Thiele 2005). Therefore, grassland in good condition would also have these attributes.

3. MODEL DEVELOPMENT

The basic components of the nine Natural Ecosystems were identified in a workshop undertaken by the Parks Victoria research branch. This work has been used as a basis for further investigations into the Natural Ecosystems and sub-ecosystems, including a review of management and planning documents, an elicitation process with experts and ongoing involvement and consultation with Parks Victoria research, conservation and on-ground staff.

There are a number of steps in model development, outlined as follows (see also Figure 3.1):

1. Initial work was carried out by Parks Victoria to identify the most important values, threats and management responses for each of the Natural Ecosystems.

2. Gathered and consolidated information and knowledge of Natural Ecosystems and sub-ecosystems from the published literature, internal and external reports and planning documents.
3. Developed a first draft of each model (a concept map and a causal model) for each Natural Ecosystem or sub-ecosystem.
4. Undertook multiple rounds of feedback and model refinement. This process is ongoing and should continue into the future.

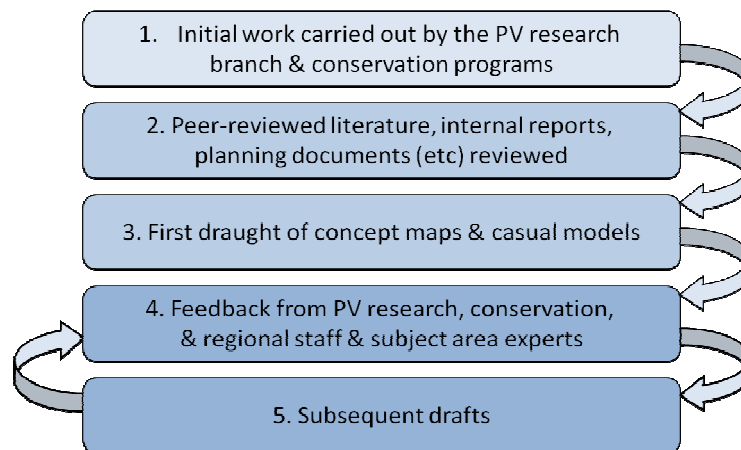


Figure 3.1: Outline of the process used to develop the concept maps and causal models for each Natural Ecosystem or sub-ecosystem.

3.1. Concept Maps & Casual Models

The concept maps capture all of the variables that are important in determining the state or condition of the ecosystem under consideration. The casual models have the same components as the concept maps, but the components are linked with arrows to indicate causal relationships. These links capture the important interactions as we understand them, but do not indicate if the relationship is positive or negative (*i.e.* if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition;

- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition;
- **Threatening processes:** the process through which the threats influence system structure, function, state or condition;
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes;
- **Resulting habitat structure:** the habitat that results from the combination of threats acting on a system and the management responses:
 - Includes important habitat components (descriptive), *e.g.* tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat; and
 - Highlights the sorts of things that we could monitor ('indicators') in order to make a judgement about condition or state of a system; and
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

3.1.1. Drivers

For the broad Natural Ecosystems (or sub-ecosystems) considered here the main drivers are climate, rock type (a major determinant of soil type), topography and topographic position, which together determine variations in nutrient availability and hydrology. At this scale environmental and climatic characteristics have produced recognizable and characteristic vegetation communities, which have characteristic soil properties, fire regimes, rainfall and temperature patterns and inundation regimes. As well as these natural drivers there are anthropogenic drivers, such as past landuse, which, through clearing and degradation, influence the distribution, condition and functioning of ecosystems.

Fire regime: This variable describes the ecologically appropriate fire regime for each Natural Ecosystem (or sub-ecosystem), based on the maintenance of species that are typical of the EVDs that make up that system (tolerable fire intervals for EVDs have been taken from Cheal 2010). The plant species that make up a vegetation community are strongly influenced by fire and the persistence of individual species are often directly linked to a particular fire regime (Cary and Bradstock 2003). Landscapes and biological systems have been shaped by fire on a geological time scale and by recent fire regimes (Cary 2002). The details for this variable are taken from Cheal (2010), in the form of a minimum fire interval for low severity fires, a minimum fire interval for high severity fires, and a maximum fire interval. The

minimum and maximum fire intervals for an EVD are based on the attributes of the Key Fire Response Species (McCarthy et. al, see www.parkweb.vic.gov.au/resources/14_0978.pdf) – those species whose persistence is relatively sensitive to a short or long fire interval.

Low severity fires tend to be patchy, the canopy is rarely burnt, resprouting is rapid and there is no significant impact on structure. This is in contrast to high severity fires where the canopy is usually consumed, structural change is likely and recovery will take significantly longer (Cheal 2010).

Soil: This variable describes the soil characteristics that are typical of the particular Natural Ecosystem (or sub-ecosystem). Soils vary according to particle size, chemistry and depth. These properties determine soil fertility (the nutrients present and their availability) and structure, which determines drainage and water storage capacity. Organic content and depth of surface litter are other important soil characteristics. Vegetation and biological soil crusts (lichens and mosses) protect soils from erosion. Managed herbivores (sheep and cattle) and feral herbivores (rabbits, horses, hare and goats) may reduce the cover of vegetation and soil crusts, and result in accelerated erosion (Attiwill and Weston 2003).

Aspect and Elevation: Climatic conditions vary with topography at a broad scale (*e.g.* temperature decreases and rainfall increases with increasing elevation), and at smaller scales (*e.g.* temperature and solar radiation vary with aspect, southern slopes receiving less solar radiation, and generally being moister and cooler). Aspect and elevation have been included where they are an important influence in determining where a Natural Ecosystem (or sub-ecosystem) occurs.

Rainfall: Rainfall varies in Victoria in a gradient from the south-east (the wettest areas) to the north-west (the driest areas), see Figure 3. This has a major influence on the distribution of vegetation communities in Victoria; for example, canopy height and projected foliage cover decrease with decreasing rainfall (Johnson 2003).

Past landuse: This variable describes the most widespread land uses which occurred in each Natural Ecosystem (or sub-ecosystem) prior to reservation. Land uses include cropping, grazing, mining, forestry and urban development. Some ecosystem types have been affected to a greater or lesser degree than others; those most suitable for agricultural development are often the most depleted in area and condition.

Ecosystem productivity: Ecosystem productivity (influenced by rainfall and soil fertility) affects the growth rate of vegetation and the rate of recovery after disturbance. It also determines the rate at which certain important habitat components are produced (*e.g.* hollows and coarse woody debris).

Inundation regime: This variable is included for systems that depend to some degree on periodic (or permanent) inundation, and is a summary of information found in EVCs / Bioregion Benchmarks.

3.1.2. Threat agents

These variables include the past and present activities (and other factors) at the start of a causal chain that influence the state or condition of the ecosystem.

Weed propagules: These may be invading new areas or increasing the abundance of a weed species in an already invaded area. There are many vectors for weed propagules, including vehicles, people and native and introduced animals. Weed propagules may also be introduced into areas via wind and water. Areas with a higher edge to area ratio are more prone to edge effects, which include the introduction of weed propagules. The main impacts of weed species are that they reduce or prevent the regeneration or establishment of native plants, alter the structure and composition of vegetation communities and can result in the loss of habitat for dependent native fauna.

Illegal activities: These include the theft of flora and fauna (*e.g.* orchids and other wildflowers, parrots, reptiles), resulting in decreased population size or loss of species. Rubbish dumping, which can lead to the pollution of waterways and soil and/or the poisoning of wildlife. The use of vehicle tracks out of season and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion. Other illegal activities include unauthorised firewood collection, shooting ducks out of season, bringing domestic pets into the park (particularly dogs), and poaching of game (*e.g.* deer).

Recreational activities: These include the use of bicycles, motor bikes and cars (may include four-wheel driving), and horse riding and hiking, which can result in soil disturbance and erosion, and the introduction and spread of weeds and pathogens. They also include camping (soil erosion and compaction, pollution of waterways); prospecting (soil erosion, loss of vegetation); duck shooting (shooting of non-target species); abseiling and rock climbing (damage to rocks, cliffs and sites of archaeological significance); fishing (reduction in diversity and abundance of native fish species); and boating (the removal of snags, bank erosion and sedimentation and water pollution). Firewood collection occurs in some parks (may be legal or illegal); this reduces the habitat for ground-dwelling animals (mammals, birds, reptiles and invertebrates).

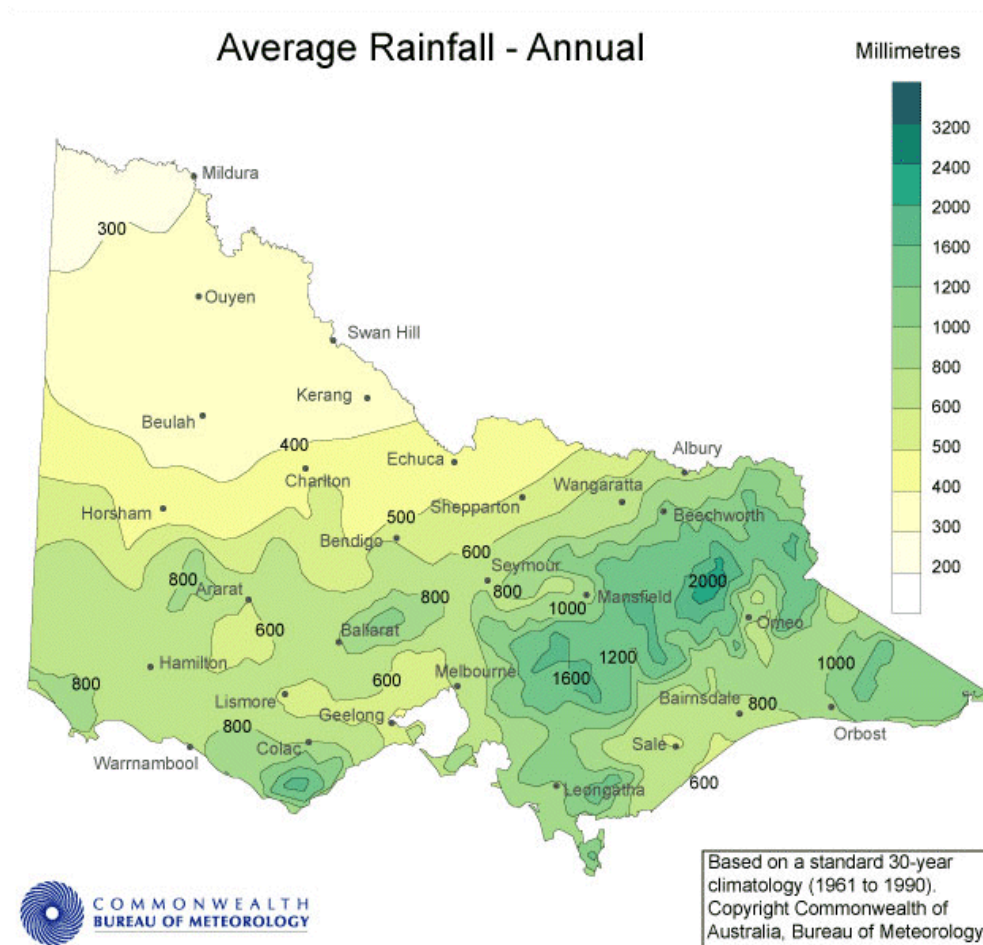


Figure 3.2: Average annual rainfall across Victoria, taken from the Bureau of Meteorology website, www.bom.gov.au.

Climate change: CSIRO (2007) projections for Victoria indicate that average temperatures will increase by approximately 0.8°C with a range of 0.6-1.2°C by 2030, and that by 2070 under a low emissions scenario the increase will be around 1.4°C (range 0.9-2.0°C) and under a high emissions scenario around 2.7°C (range of 1.8-3.8°C). Modelled results from seasonal simulations predict decreases in rainfall for all seasons; but the greatest decreases are expected in spring. Predictions are for fewer rainy days but increasing rainfall intensity (CSIRO 2007). The greatest increases in temperature are expected in summer, and droughts are expected to be more frequent, longer and hotter (CSIRO 2007). An increase in potential evaporation is predicted over much of the continent, and this combined with reduced rainfall is likely to increase moisture stress. These factors would result in decreased average run-off to streams, and hotter, drier conditions are likely to increase the risk of bushfire. This is likely to lead to changes in the structure and composition of native vegetation communities, and impacts on biodiversity (*i.e.* the loss of flora and fauna species).

Inappropriate fire regime: The fire regime takes into account those variables important in determining the ecological impact of fire, including fire intensity, type (e.g. subterranean, surface, crown), between-fire interval and season of fires (Gill 1975, Cary and Bradstock 2003). An inappropriate fire regime will fail to maintain the typical species composition of the ecosystem type. For example, the interval between fires may be too long or too short, or fire intensity may be insufficient to release the seeds of one or more important species. An inappropriate fire regime will lead to a change in the composition and structure of native vegetation, and the loss (or reduced abundance) of dependent fauna.

Inappropriate fire management & suppression methods: These can include the creation of fire breaks/access tracks in vegetation types that are sensitive to disturbance (where natural recovery is unlikely and/or restoration is difficult), or in areas that may already be highly fragmented. It may also include the use of fire retardants and wetting agents and foams. The impacts of fire breaks and access tracks include habitat loss and fragmentation (increasing edge effects), soil erosion (increased turbidity and sedimentation of waterways), soil compaction (from the use of heavy machinery) and weed invasion. They also create a barrier to migration for native fauna and increased passage way for introduced pest plants and animals. Runoff containing fire retardants, wetting agents and foams may have adverse effects on aquatic plant and animal species. In vegetation communities that have naturally low nutrient levels they may provide conditions favourable for weed growth.

Grazing/browsing by introduced herbivores: The impacts of introduced herbivores include changes in vegetation structure and composition (preferential grazing, and differential response of vegetation to mechanical damage and to changes in nutrient availability), loss of litter and biological soil crust, soil compaction (which decreases infiltration and increases overland flows, compaction also affects the ability of plant roots to utilize the soil), and the creation of bare ground which is then vulnerable to erosion and weed invasion (Yates and Hobbs 1997). Introduced herbivores may also inhibit or prevent regeneration of native plant species.

Grazing/browsing by overabundant native herbivores: Native herbivores, when in large numbers, may change vegetation structure and composition (more palatable species become less abundant), inhibit regeneration, and create bare ground which is then vulnerable to erosion and weed invasion. Browsing by overabundant Koala populations is a cause of dieback, and may eventually result in tree death. The increased availability of water (e.g. farm dams, reservoirs) allows kangaroo populations to be sustained at artificially high densities during dry periods, and may lead to overgrazing.

Past clearing: Vegetation in Victoria has been extensively cleared for forestry and to make way for cropping and grazing, urban development and mining. This has resulted in habitat

loss, fragmentation of remaining vegetation, changes in the distribution and abundance of flora and fauna and species extinctions. Catchment clearing has had the effect of decreasing infiltration, reducing base flow to streams, and increasing flood peaks. Other impacts include erosion and the generation of sediment, which can smother in-stream habitat and biota, and degrade water quality.

Adjacent land use: Parks and reserves are surrounded by many different land uses and these can have impacts on the ecosystems within parks. Agriculture and urban development in surrounding areas are a potential source of weed propagules, and runoff containing nutrients, pesticides and herbicides (leads to mortality of susceptible species and changes to in-stream macroinvertebrate communities). Urban storm water runoff may also contain sewage effluent and pollutants (*e.g.* heavy metals), and due to the increase in impermeable surfaces runoff from urban areas produce high peak discharges to local waterways. The modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Introduced predators: These include foxes, cats and dogs. Introduced predators have the effect of decreasing the population size of small mammals, herpetofauna and ground foraging/nesting birds. Ground-dwelling mammals, birds and reptiles are particularly vulnerable to foxes, a species which also spreads pest plants such as Blackberry.

Inappropriate water regime: This variable is included for water dependent ecosystems. An inappropriate water regime will fail to maintain the typical species composition of that ecosystem type. The water regime includes timing of in-channel and overbank flows, flood volume (for overbank events), flood frequency, flood duration and the maximum time between flood events. It also includes the loss of drying events due to artificially perennial flows. An inappropriate water regime will result in changes to the composition and structure of native vegetation communities, the loss of habitat for dependent fauna, and reduced diversity and abundance of in-stream biota.

Barriers to water movement: Barriers to water movement may be longitudinal (*e.g.* dams and weirs) or lateral (*e.g.* levees and other floodplain developments). Longitudinal barriers obstruct fish movement (creating isolated populations, excluding individuals/populations from breeding and feeding habitat), and reduce the transportation of sediment, plant propagules and aquatic invertebrates. They also reduce flow velocities allowing sediment deposition in weir pools, destroying important habitat. Lateral barriers restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (flooding is an important source of nutrient input into the channel) (Overton *et al* 2009). Facilitating overbank flows onto the floodplain is important for maintaining carbon and nutrient cycles, and access of riverine species to floodplain habitat for breeding. Without overbank flows

floodplain habitats that rely on periodic inundation become degraded, there is a reduction in (or absence of) regeneration events and tree species may show sign of dieback (e.g. Redgum and Black Box woodlands).

De-snagging: De-snagging is the removal of fallen trees and branches from the river channel and was undertaken to improve the passage of boats. The impacts of de-snagging include increased flow velocity, bed degradation, channel enlargement and loss of fish and invertebrate habitat. A number of native fish species are dependent on snags for habitat, to shelter from currents, and to feed and spawn. Snag dependent species include Murray cod, Trout Cod and Golden Perch (Robson *et al* 2008).

Channelization: Channelization of streams and rivers was undertaken to improve navigation and increase channel capacity, and also to extract sand and gravel. Channelization increases flow velocity, reduces habitat diversity (particularly areas of slack water), cover and shelter, food sources and spawning areas. It also produces sediment, which can smother habitat and biota.

Introduced fish species: Introduced fish species include carp (*Cyprinus carpio*), mosquito fish (*Gambusia holbrooki*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*). Introduced fish significantly impact on native fish through predation, and competition for food and habitat. In addition, Carp increase water turbidity and damages aquatic plants.

Introduced bees: Introduced bees compete for habitat (e.g. tree hollows) with native fauna. They also compete for food and other resources with native bees and birds, and may cross-pollinate native plants and increase the cover of pest plants.

Prospecting/fossicking: This activity requires a permit. It typically involves the use of metal detectors, hand tools, pans and/or sluices in the search for gold, gemstones and other minerals. Excavation is permitted but only with hand tools; it is not permitted to remove vegetation and holes must be back filled. Prospecting/fossicking occurs in some ecosystem types, most notable Box-Ironbark forest. Impacts can include the inadvertent loss of native vegetation and soil erosion.

Phytophthora: *Phytophthora cinnamomi* is a water mould that attacks the root systems of susceptible native plant species, causing plant mortality. This can change the composition and structure of native vegetation communities, and result in the loss of habitat for dependent fauna. Rainfall, temperature and soil characteristics determine the distribution of Phytophthora (warm, wet soils with impeded drainage are ideal). Susceptible plant families are Proteaceae (e.g. *Grevillea*, *Hakea*), Fabaceae (peas), Dilleniaceae (e.g. *Hibbertia*) and Epacridaceae (heaths) (DSE 2008).

Myrtle Wilt: Myrtle Wilts affects the tree species *Nothofagus cunninghamii* and is caused by infection with the native fungus *Chalara australis*. The fungus invades either via wounds on the outer bark or root contact with infected plants, and may be exacerbated by damage caused during management activities (e.g. road and track construction and maintenance). The fungi spreads by air and water-borne spores, and infection makes trees more prone to attack by borers. The incidence of Myrtle Wilt decreases with elevation, probably because the decreasing temperatures inhibit fungal activity (DSE 2005), rising temperatures with climate change may reduce this effect. Myrtle Wilt is a serious problem in parts of the Great Otway National Park and in the central highlands.

Firewood collection: Collection of firewood is permitted in some parks and reserves. Dry firewood and green fallen firewood may be collected from designated locations. A permit is required and there are limits on the amount that can be taken. Firewood collection reduces available habitat for ground dwelling mammals, birds, amphibians, reptiles and invertebrates (see Brown *et al* 2009).

3.1.3. Threatening process

These are the process through which the threats influence system structure, function and state or condition.

Weed invasion: Whether a weed species is able to successfully invade an area is determined by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place (e.g. particular burning regimes, herbicide use and/or manual removal of weeds). Site characteristics will determine whether the weed propagules that reach a site will be able to germinate and establish. Disturbance favours plant invasions by increasing resource availability while also decreasing competition from resident species, making the recruitment phase of invasion possible (Hobbs and Huenneke 1992). This is why a closed cover of native vegetation is a major factor in reducing the probability of weed invasion (Burke and Grime 1996). The success of weed species is enhanced by nutrient enrichment, which promotes the growth and reproduction phases (Burke and Grime 1996). Fire provides bare ground and an input of nutrients and hence favours the invasion of exotics. Hobbs and Huenneke (1992) found that the interaction of several different types of disturbance led to the highest rates of weed invasion. Weed invasion alters the composition and structure of native vegetation communities, and leads to the loss of habitat for dependent fauna.

Soil erosion/degradation/bare ground: Land clearing for agriculture and the introduction of herbivores (managed and feral) have lead to the reduction in the cover of vegetation and biological soil crusts, increased the area of bare ground and lead to soil compaction. Bare

ground provides the opportunity for soil erosion and the invasion and establishment of weed species. Soil compaction impedes root growth, soil water recharge and water availability (Yates and Hobbs 1997). Increased erosion leads to sedimentation and smothering of stream beds and biota and degrades water quality.

Degradation of biological soil crust: Biological soil crusts are made up of species of mosses, liverworts, cyanobacteria, algae, lichens, fungi, and bacteria, growing on and within the uppermost layers of the soil. They stabilize the soil against water and wind erosion, regulate the flow of water into soils, and provide a sink for soil carbon. In addition, organisms in the crust produce nitrogen, provide sites for the establishment and survival of plant seedlings, and provide niches for soil invertebrates that are important for the process of decomposition and mineralization (Eldridge 2000).

Overgrazing: Overgrazing occurs when the overall grazing pressure (from introduced and native species) is unacceptably high, and is measured by using key indicators such as vegetation condition. Overgrazing degrades vegetation condition and changes vegetation structure and composition (reducing the cover and abundance of palatable species while increasing the cover and abundance of less palatable species). Overgrazing may also contribute to soil erosion and compaction, and conditions that are favourable to weed invasion (includes soil disturbance and creation of bare ground, and the addition of nutrients). The grazing pressure can be reduced by management activities.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter drought (CSIRO 2007). Among the potential impacts of increased drought are a decrease in flowering and nectar flow (Law and Chidel 2009); a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire intensity and frequency.

Fire too frequent (interval too short): Intervals less than the minimum fire interval (see Cheal 2010), estimated using Key Fire Response Species. May result in loss of species where the inter-fire interval is not adequate to allow individuals to reach reproductive maturity and produce a viable amount of seed (loss of these species in the seed bank) or become vegetatively viable. This may lead to changes in vegetation structure and composition, and the loss of dependent fauna. Also, may result in the loss of old, hollow-bearing trees, and reduce the amount of woody debris, which are important components of faunal habitat.

Fire not frequent enough (interval too long): Intervals greater than the maximum fire interval (see Cheal 2010), estimated using Key Fire Response Species. Impacts include changes to the composition and structure of native vegetation, possible loss of fire adapted species and increased cover and abundance of fire-intolerant species. An example is the

invasion of rainforest species into surrounding eucalypt forest in the long term absence of fire.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of habitat, which has affected the distribution and abundance of many plant and animal species. Existing (remnant) habitat may also be under pressure from degrading processes which can contribute to further habitat loss. Vegetation clearing has contributed to soil erosion, sedimentation of waterways, and soil salinization.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. These remnant areas of vegetation occur as islands of habitat surrounded by a matrix of land developed for agriculture or other purposes. This changes the distribution and movement of water and nutrients, and affects the way wind and radiation vary across the landscape (Saunders *et al* 1991). Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Vegetation clearing creates patches of habitat which have an increased edge-to-area ratio. This can result in increased exposure to weed propagules, dust (and other particulate deposition), insect attack, predator incursions, nutrient enrichment and soil disturbance. Biota at or near the edge of an area of remnant vegetation may be affected by changes in the microclimate (*e.g.* fluxes of wind, radiation and water) which influence humidity and soil moisture.

Overly dense regrowth stands: Tree density is very high in some areas due to past disturbance. In these areas there are very few large, old, hollow-bearing trees, which impacts on the availability of fauna habitat (hollows and woody debris).

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. These include insect attack (may be accompanied by a decrease in insectivorous birds), overabundant herbivores (*e.g.* koalas), changes to microclimate caused by edge effects (*e.g.* changes to wind and radiation fluxes), soil compaction, salinity, drought, nutrient enrichment, disease (*e.g.* Phytophthora, Myrtle Wilt) and/or altered hydrology (includes inappropriate inundation regime; length of inundation and/or water stress between floods). Stressed trees are generally more susceptible to the effects of dieback.

Salinity: Soil salinization occurs when the water table rises, bringing with it salt that occurs naturally in the soil profile. The water table has risen in irrigated areas and areas where native deep-rooted perennial species have been replaced with herbaceous crop and pasture species (reducing the amount of evapotranspiration). Salinity reduces the diversity of native plants and animals, changes the composition and structure of native vegetation communities and may lead to soil erosion, reduced water quality in streams and rivers, and loss of riparian

vegetation. Increased salinity threatens the habitat of fish and aquatic invertebrates, which in turn provide a food source for waterbirds.

Reduced water availability: This may result from extraction of water for human use (see Inappropriate Water Regime), and increased drought from climate change (see Increased Drought). It includes consideration of an overall reduction in water availability and/or reductions in seasonal availability.

Nutrient enrichment: Nutrient enrichment in terrestrial systems may result from wind and water deposition, sources include crop fertilization, manure and animal feed (Duncan *et al* 2008). In aquatic systems it involves increased nutrient delivery (particularly of nitrogen and phosphorus) to waterways from runoff, and may result in eutrophication and an overgrowth of algae (see 'algal blooms' below). Nutrient enrichment also has impacts on terrestrial and aquatic flora and fauna, and contributes to poor tree condition and the incidence of dieback.

Algal blooms: Algal blooms have amenity and health impacts, but also reduce dissolved oxygen, and may result in the death of fish and other aquatic biota. Elevated nutrients and/or increased water temperature contribute to the incidence of algal blooms.

Reduced connectivity: Barriers to water movement may be longitudinal (*e.g.* dams and weirs) or lateral (*e.g.* levees and other floodplain developments). Longitudinal barriers obstruct water and fish movement (creating isolated populations, excluding individuals/populations from breeding and feeding habitat), and reduce the transportation of sediment, plant propagules and aquatic invertebrates. Lateral barriers restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (flooding is an important source of nutrient input into the channel) (Overton *et al* 2009). Some wetlands are now isolated from their water source (*e.g.* a number of River Murray Icon sites), and water may need to be pumped from the river channel to maintain these habitats.

Channel modification: River and stream channels can be modified in many ways, including de-snagging, dredging, straightening and damming. Channel modification has been undertaken in the past to improve navigation and increase channel capacity, improve drainage, and to facilitate water extraction, storage and transportation for irrigation and other uses.

Increased water temperature: The reduction in fringing vegetation has the effect of increasing water temperature, which has effects on aquatic flora and fauna, and may be a factor in the increased occurrence of algal blooms. Global warming is also likely to increase water temperature.

Sedimentation: Soil erosion caused by land clearing, agriculture and forestry leads to an increase in suspended solids and turbidity in rivers and streams. When these settle the river bed is smothered, altering habitat and causing mortality in some species of flora and fauna. There may be a large pulse of sediment after major disturbances such as fire.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. Predators include foxes, cats and wild dogs, and in aquatic habitats include introduced fish species. Prey animals include mammals, birds, reptiles, amphibians, fish and invertebrates.

3.1.4. Management response

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. The II&E program is delivered using various means, including websites, brochures, and marketing campaigns, tourism and other publications, signage and displays, education programs and via licensed tour operators, as well as on-site awareness building such as open days, special events, functions and tours. These can be developed and provided in collaboration with Friends and other community groups and individuals, government bodies and other organisations.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. When this involves illegal or unauthorized activity the offender may be issued with a fine or referred to police. Several education programs are in place to inform and motivate people to look after parks, and the native plants and wildlife that occur within their boundaries. Impacts of illegal activity are minimised through information, education and interpretation programs and through surveillance and enforcement. The impacts of recreational use of a park may need to be monitored, and management strategies or policies modified.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the species natural enemies). The most effective approach is usually to use a number of different strategies ('integrated weed management'), which reduces the likelihood that a weed species will adapt to a particular control technique (especially the development herbicide resistance). Any weed management strategy should also take into account the broader impacts of weed removal (*e.g.* soil disturbance and erosion), should aim

to reduce the extent of weeds and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire Management Program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using Key Fire Response Species (McCarthy et. al, see www.parkweb.vic.gov.au/resources/14_0978.pdf), which are used to set the minimum and maximum tolerable fire intervals (see Cheal 2010).

Fire breaks and management tracks: Fire breaks and management tracks contribute to the effects of fragmentation (increased edge effects, barrier to of flora and fauna movement), and may lead to soil erosion and compaction, increased turbidity of waterways, weed invasion and increased passage for pest plants and animals and plant pathogens such as *Phytophthora*. Placement of fire breaks and management tracks should be sensitive to these issues.

Grazing Management: Grazing management may target introduced herbivores (e.g. rabbits, goats) and/or overabundant native herbivores (kangaroos and koalas). The key consideration is the overall grazing pressure (from introduced and native herbivores) as determined from monitoring of key indicators (e.g. vegetation condition, regeneration of woody vegetation). The increased availability of water in some habitats has allowed populations of kangaroos (and some other species) to be sustained at artificially high densities during dry periods. Diversity and abundance of native plant species may need to be monitored to determine the carrying capacity in these situations. Limiting access to water (fencing or decommissioning water sources within parks, fencing at park boundary to limit access to water and pasture) helps to control goat and kangaroo populations. Kangaroo, goat, pig and rabbit populations may be controlled by culling. Rabbit management may also include poisoning, ripping, fumigation and biological control. The management of overabundant koala populations may involve a number of methods including translocation, fertility control and habitat manipulation (protection of individual trees).

Phytophthora containment & hygiene measures: Containment and hygiene measures are used to minimise the spread of *Phytophthora cinnamomi*. Procedures include management (or minimization) of movement of people, vehicles, equipment and other materials from infected into uninfected sites, and may include wash-down facilities. Other considerations include road placement, movement of gravel, road grading operations, drainage and management of vehicle tracks and fire operations.

Myrtle Wilt Management: The management of Myrtle Wilt may include the minimisation of tree wounding, breaking of root grafts (connections) between infected and uninfected trees, and/or the active management of regeneration in infected stands (DSE 2005).

Restoration: Different restoration methods are applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas. For Inland Waters and Wetlands restoration may include reinstatement of the natural flow regime and vegetation composition, and control of access to the waterway or wetland.

Predator control: Predator control in Victoria targets mainly foxes (poison baits using 1080), cats (trapping and shooting) and wild dogs (poison baits using 1080). Monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

Ex-situ catchment management: Ecosystems within parks are affected by the activities that occur in the wider catchment area. These areas are managed by a variety of bodies that are guided by natural resource and catchment planning frameworks, which through a system of strategies and plans aim to address catchment-wide issues. Among these are programs to improve water quality, decrease sediment and nutrient delivery to waterways and wetlands, reduce flood peaks and increase the proportion of water that is delivered to waterways as base flow (as opposed to quick flow). It also includes the management of catchments to reduce the risk of lakes, wetlands and waterways from becoming salt-affected (*e.g.* salt interception schemes, improved land management to control salinity and waterlogging).

Ecological thinning: Ecological thinning is the process of removing some smaller trees and allowing remaining dominant trees to grow faster and ultimately larger. Older, larger trees have hollows and other features which provide crucial habitat for many birds and mammals.

Environmental water delivery: Environmental water delivery is often necessary to maintain the health of Inland Waters and Wetlands, which will usually include the maintenance native vegetation community composition and structure. The deviation from the natural flow regime is used to estimate 'flow stress' and includes consideration of volume of flows, timing, frequency and the maximum time between flows. Environmental water delivery may include strategic water delivery to areas that rely on overbank flows, *e.g.* pumping from the river channel into wetlands, billabongs, lagoons, etc.

3.1.5. Resulting habitat structure

The 'resulting habitat structure' represents the habitat that results from the combination of threats acting on a system and the management responses. It includes description of important habitat components, *e.g.* tree layer, understorey, ground cover, tree hollows, woody debris and in-channel habitat. The main (largest) box in each ecosystem model highlights the sorts of things that we could monitor ('indicators') in order to make a judgement about condition or state of a system (see Section 2.1).

The causal models indicate where specific threats act on specific habitat components or values, and where specific habitat components are important to specific values. Broad threats act on all habitat components and lead directly to the main habitat box in the model; specific threats affect the main habitat box through the other habitat components.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (*e.g.* clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (*e.g.* firewood collection, fire).

3.1.6. Priority values

These were defined in the initial workshop undertaken of Parks Victoria staff, and then subsequently refined in further consultation and discussions. They represent an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

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6. APPENDIX: ECOSYSTEM CONCEPTUAL MODELS

6.1. Dry Forest & Woodland – Box-Ironbark Forest (EVD24)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are split up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate, manage, or ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.1.1. Drivers

Fire regime: Minimum fire interval for low severity fires (patchy, canopy rarely burnt) is 12 years, and high severity fires (canopy consumed) is 30 years (Cheal 2010). The maximum fire interval is estimated at 150 years, though this vegetation type is unlikely to be replaced by another vegetation type in the absence of fire (Cheal 2010). This ecosystem type has generally low fuel loads, and high severity fire is rare.

Soil: Most of the remaining Box-Ironbark forest occurs on shallow infertile soils (Mac Nally et al. 2009). Some remnants occur on better soils in along roads and streams (Johnson et al. 2007).

Rainfall: Low, long dry summers, few permanent streams occur in this ecosystem type.

Past landuse: Disturbance in this ecosystem type has been intense and widespread over the last ~160 years. Approximately 80% of Box-Ironbark has been cleared in the period since European settlement (PV 2007). Forest was cleared for agriculture, mining and timber harvesting; as a result the trees in this habitat are mostly coppice regrowth.

Ecosystem productivity: Relatively low, recovery (including succession) is generally very slow (though there are better prospects for recovery at sites with better, more fertile soils).

6.1.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include grasses (e.g. Squirrel-tail Fescue) and herbs species (e.g. Cat's Ear and Smooth Cat's Ear). St John's Wort is a concern in some parks.

Recreational activities: These include the use of mountain bikes, motor bikes and cars, and horse riding, hiking, camping and prospecting/fossicking (see below).

Illegal activities: These include the theft of flora and fauna (e.g. orchids, herbs and parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Introduced bees: Introduced bees compete for habitat (e.g. tree hollows) with native fauna. They also compete for food and other resources with native bees and birds, and may cross-pollinate native plants and increase the cover of pest plants.

Prospecting/fossicking: This activity requires a permit. Excavation is permitted but only with hand tools; it is not permitted to remove vegetation and holes must be back filled. Impacts can include the inadvertent loss of native vegetation, the creation of bare ground and soil erosion.

Climate change: Climate change projections for Victoria include increased drought, reduced runoff, increased risk of bushfire and longer bushfire seasons. This is likely to lead to changes in the structure and composition of native vegetation communities, and the loss of some flora and fauna species. The most important impact of climate change on these systems is likely to be increased drought, which will impact on flowering and nectar production. Climate change may also increase fire frequency and may result in out-of-season fires.

Inappropriate fire regime: Fire too frequent (intervals less than 12 years for low severity fire and less than 30 years for high severity fire), also some vegetation components possibly sensitive to the time of year that fire occurs (Tolsma et al. 2007).

Introduced herbivores: Include rabbits and goats.

Overabundant native herbivores: Over-abundant native fauna, kangaroos and wallabies. Probably rely on the water supply in adjacent land (farm dams etc).

Past clearing: Box-Ironbark forest was extensively cleared for mining, forestry and urban development, and the recovery of this forest type has produced even-aged multi-stemmed stands, with very few large, old hollow-bearing trees. This ecosystem type is highly fragmented.

Adjacent landuse: May be a source of weed propagules, provide a water and food source to elevate native herbivore numbers, which may then come into the park to browse vegetation. The modification of remnant vegetation on adjacent private land may also increase the effects of fragmentation.

Firewood collection: Firewood collection is permitted in some parks. Dry firewood and green fallen firewood may be collected from designated locations. A permit is required and there are limits on the amount that can be taken. Firewood collection reduces available habitat for ground dwelling mammals, birds, reptiles and invertebrates.

Introduced predators: Includes foxes, cats and wild dogs.

6.1.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Soil disturbance from practices employed in mining have resulted in highly disturbed soil in this ecosystem type. Current prospecting and fossicking could potentially lead to further soil degradation and erosion. Other land uses

(including clearing and grazing) have reduced the cover of vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Bare ground provides the opportunity for the invasion and establishment of weed species. Soil disturbance and compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Poor flowering and nectar production: Poor flowering and nectar production has been observed over the past 12 years of drought (Mac Nally et al. 2009). There has been an observed decline in bird populations due to low breeding success, brought on by reduced food availability (Ibid).

Season of fire: This ecosystem type may be sensitive to the time of year that a fire occurs. Some information is provided by work at Reef Hills State Park, which showed that ground flora (mainly grass species) responded differently according to the season of the burn.

Fire too frequent (interval too short): Intervals less than 12 years for low severity fire and less than 30 years for high severity fire. May result in loss of species where the inter-fire interval not adequate to allow species to reach reproductive maturity and produce seed (loss of these species in the seed bank). Also may result in the loss of old, hollow-bearing trees (take ~100 years to form), changes in vegetation composition and structure and loss of dependent fauna.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought are a decrease in flowering and nectar flow (particularly in eucalypts); a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire severity and frequency.

Overly dense regrowth stands: Because of past disturbance, there are large areas in Box-Ironbark forests where tree density is very high and the trees are very small in diameter (less than 10cm). There are very few large, old, hollow-bearing trees, these impacts on the availability of fauna habitat (hollows and woody debris).

Overgrazing: This may be due to introduced herbivores (goats and rabbits) or overabundant native herbivores (kangaroos and wallabies). Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground).

Habitat loss: Past land clearing has resulted in the loss and fragmentation of Box-Ironbark forest. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. Box-Ironbark forests were extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance.

Removal of woody debris: Woody debris provides habitat and food sources. It is removed as a part of firewood collection. Woody debris comes from large trees dropping branches, and takes longer to build up in low productivity forests.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.1.4. Management responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (burning, mowing, grazing, mulching, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the

maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Ecological thinning: Ecological thinning is the process of removing some smaller trees and allowing remaining dominant trees to grow faster and ultimately larger. Older, larger trees have hollows and other features which provide crucial habitat for many birds and mammals.

Grazing management: Grazing management may target introduced herbivores (e.g. rabbits) and/or overabundant native herbivores (kangaroos and koalas). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Restoration: Different restoration methods are applied to different ecosystem types. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas. Restoration in this ecosystem type may include active management of remnants that occur in more fertile parts of the landscape (Mac Nally et al. 2009).

Predator control: The applicability of monitoring and predator control programs are guided by management and conservation objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.1.5. Resultant habitat structure

Tree species: *E. microcarpa* (White Box), *E. polyanthemos* (Red Box), *E. tricarpa* (Red Ironbark), *E. sideroxylon* (Mugga Ironbark), *E. leucoxylon* (Yellow Gum), *E. macrorhyncha* (Red Stringybark), *E. melliodora* (Yellow Box) and *E. goniocalyx* (Long-leaf Box).

Understorey: Grassy, heathy and herb-rich.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire). Hollow bearing trees are currently uncommon in this vegetation type as trees are mostly young, even-aged coppice regrowth; hollow formation and density is at a maximum ~140 years after fire.

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire). Woody debris in this ecosystem type is at a maximum ~140 years since fire.

6.1.6. References

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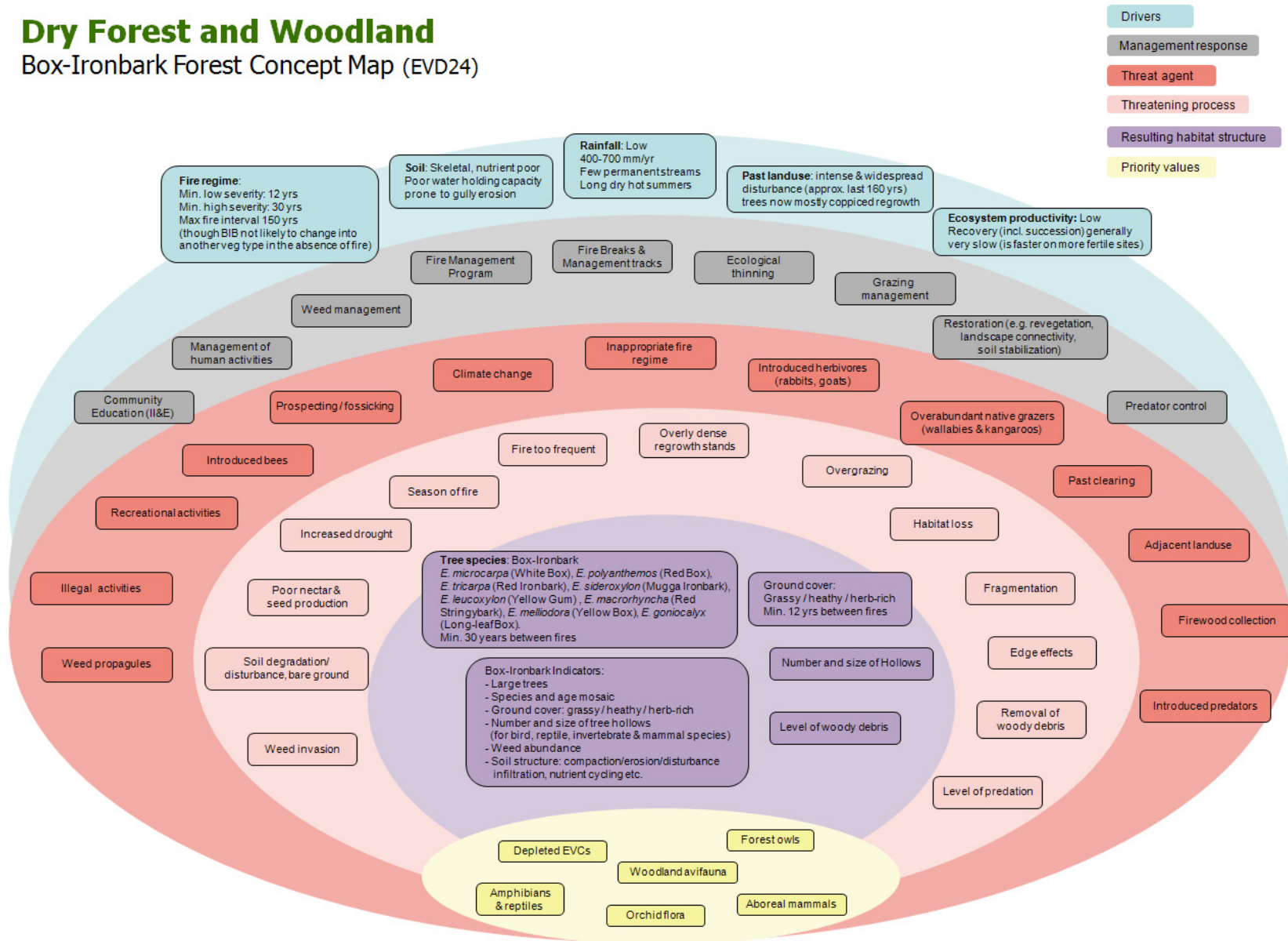
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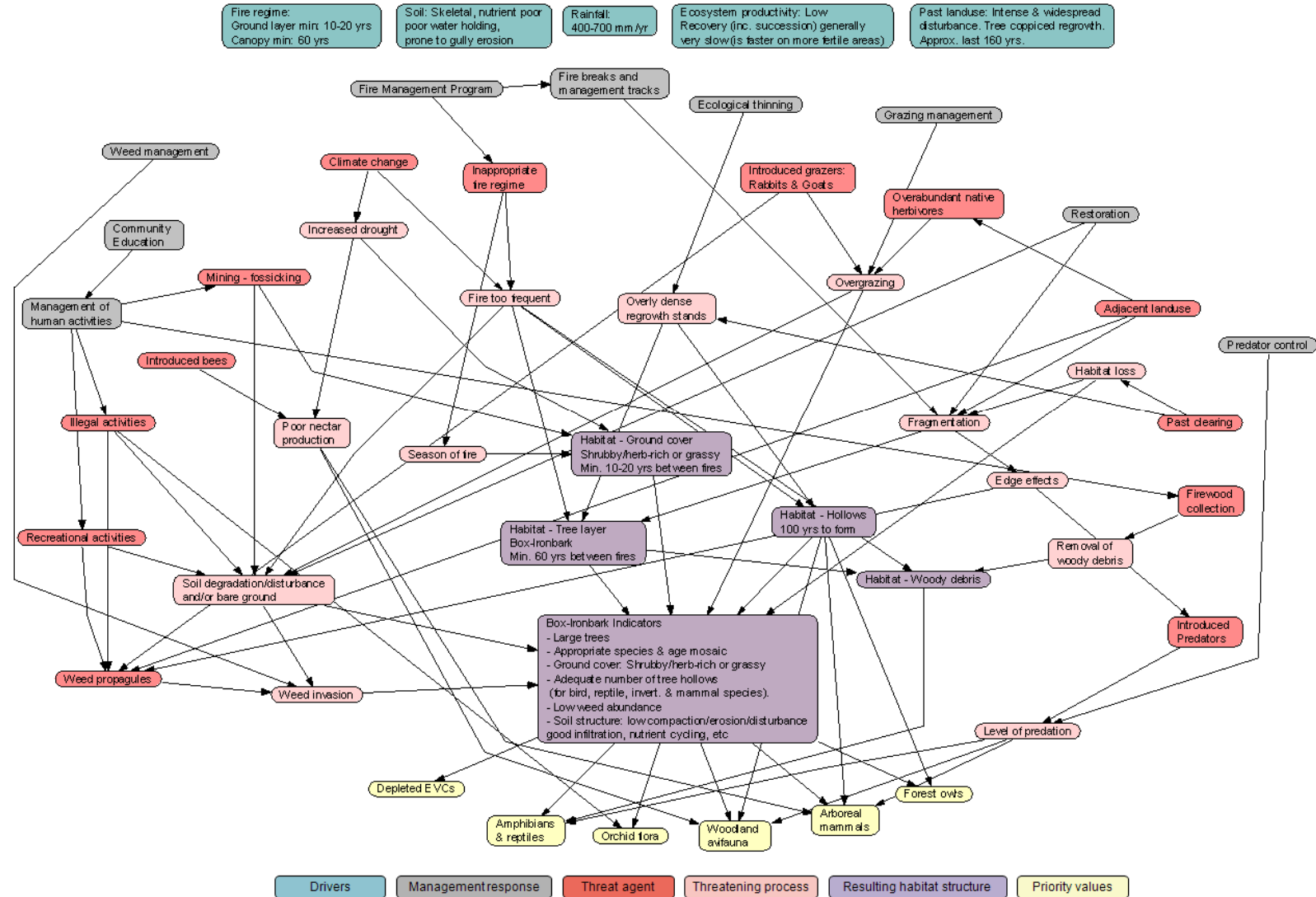
Dry Forest and Woodland

Box-Ironbark Forest Concept Map (EVD24)

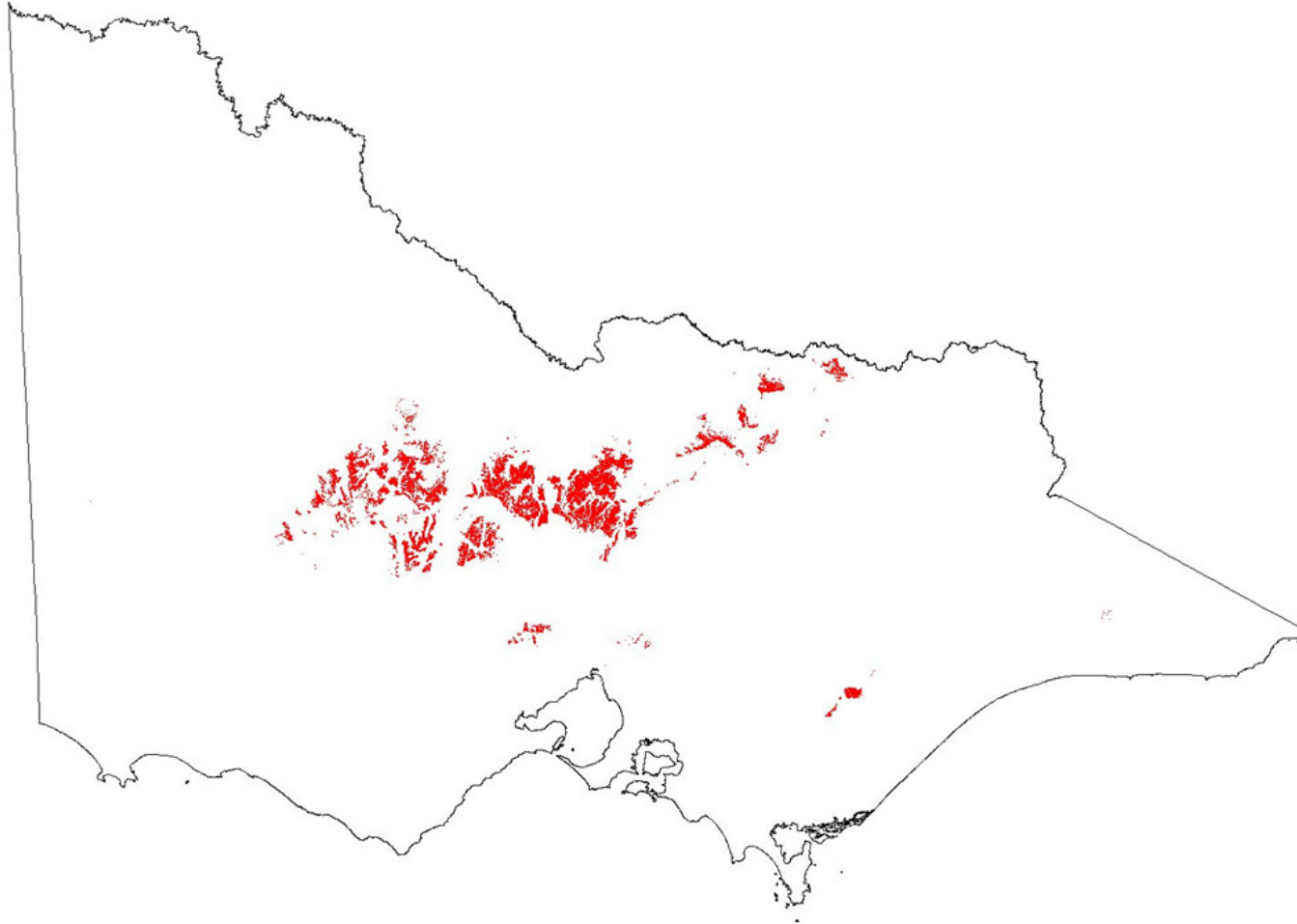


Dry Forest and Woodland

Box-Ironbark Forest Causal Model (EVD24)



EVD 24 Ironbark / Box



100 0 100 200 Kilometers



A10

6.2. Dry Forest & Woodland – Plains Woodlands (EVD19 & 23)

Includes and EVD19 (Western Plains Woodland) and EVD23 (Inland Plains Woodland).

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.2.1. Drivers

Fire regime: Dependent on which EVD is being considered, see below.

EVD19 Western Plains Woodland: Minimum fire interval for low severity fire is 4 years and for high severity fires is 30 years; the maximum fire interval is 12 years (Cheal 2010). Fires are typically patchy, high severity fires are rare and recovery from high severity fires is slow. May change into another vegetation community if unburnt for more than 12 years.

EVD23 Inland Plains Woodland: Minimum fire interval for low severity fire is 5 years and for high severity fires is 30 years; the maximum fire interval is 150 years (Cheal 2010). Fires are typically low severity and very patchy; fire not necessary for regeneration.

Soil: Loams to loamy clays; fertile, moist in winter and parched in summer.

Rainfall: Moderate rainfall with relatively low inter-annual variation.

Past landuse: Timber harvesting and clearing for agriculture and urban development.

Ecosystem productivity: Relatively high.

6.2.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). African Daisy, St John's Wort, Blackberry, Boneseed, Bridal Creeper and Sweet Pittosporum have been identified as priority pest plants in parks that contain this ecosystem type.

Recreational activities: These include the use of mountain bikes, motor bikes and cars, and hiking and camping.

Illegal activities: These include the theft of flora and fauna (e.g. orchids, herbs and parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: Climate change projections for Victoria include increased drought, reduced runoff, increased risk of bushfire and longer bushfire seasons. This is likely to lead to changes in the structure and composition of native vegetation communities, and the loss of some flora and fauna species.

Inappropriate fire regime: A fire regime is inappropriate if it does not meet the requirements of the suite of species which makes up the ecosystem type. The interval between fires may be too long or too short, or fire intensity may be insufficient to release the seeds of one or more important species. An inappropriate fire regime will lead to a change in the composition and structure of native vegetation, and the loss (or reduced abundance) of dependent fauna.

Introduced herbivores: Includes deer, rabbits and goats.

Overabundant native herbivores: Koalas have become overabundant in some areas (Mount Eccles National Park, Snake Island, French Island National Park, Raymond Island and Tower Hill Wildlife Reserve), leading to defoliation and dieback (premature tree decline and death).

Phytophthora: *Phytophthora cinnamomi* is a water mould that attacks the root systems of susceptible native plant species, causing plant mortality. This can change the composition and structure of native vegetation communities, and result in the loss of habitat for dependent fauna. Phytophthora induced dieback is recognised in some species of this ecosystem type (eastern Otways, east and south Gippsland) (DSE 2008).

Past clearing: This ecosystem type was extensively cleared for agriculture and urban development and harvested for timber. In some areas this has produced even-aged multi-stemmed stands, with very few large, old hollow-bearing trees. This ecosystem type is highly fragmented.

Adjacent landuse: May be a source of weed propagules; the modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Introduced predators: Includes foxes, cats and wild dogs.

6.2.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Bare ground provides the opportunity for the invasion and establishment of weed species. Soil disturbance and compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Fire too frequent (interval too short): May result in loss of species where the inter-fire interval not adequate to allow species to reach reproductive maturity and produce seed (loss of these species in the seed bank), e.g. *Banksia* and *Allocasuarina* species. Also may result in the loss of old, hollow-bearing trees (take ~100 years to form), changes in vegetation composition and structure and loss of habitat for dependent fauna.

Fire not frequent enough (interval too long): This will lead to increased dominance of shade tolerant *Allocasuarina* species, development of thick soil litter layer and the premature decline (in terms of potential life span) of over-storey trees, including *E. viminalis* and *E. Ovata*, due to lack of fire (Lunt 1998).

Overgrazing: This may be due to introduced herbivores (deer and rabbits) or overabundant native herbivores (koalas and kangaroos). Overgrazing leads to changes in vegetation structure and composition, and the loss of dependent fauna. Overabundant koala populations are an issue in some areas within this ecosystem type, and can cause premature tree decline and death.

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. These include insect attack (may be accompanied by a decrease in insectivorous birds), overabundant herbivores (e.g. koalas), changes to microclimate caused by edge effects (e.g. changes to wind and radiation fluxes), soil compaction, drought, salinity, nutrient enrichment, disease (e.g. *Phytophthora*) and/or altered hydrology. Stressed trees are generally more susceptible to the effects of dieback.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of vegetation in this ecosystem type. Existing (remnant) habitat may also be under pressure from degrading processes which can contribute to further habitat loss. Vegetation clearing has contributed to soil erosion, sedimentation of waterways and increased salinity.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fire breaks and management tracks also contribute to fragmentation and are common in this ecosystem type due to need to protect coastal settlements.

Edge effects: Fragmentation of habitat creates patches of remnant vegetation across the landscape. These often have a high edge-to-area ratio which can lead to edge effects such as increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance.

Removal of woody debris: Woody debris provides habitat and food sources, and is removed for firewood and by fire. Woody debris comes from large trees dropping branches, and takes longer to build up in low productivity forests and woodlands.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey

species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.2.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy parks. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. A number of education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (burning, mowing, grazing, mulching, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, based on the Key Fire Response Species (which are used to set the minimum and maximum desirable fire intervals).

Fire breaks and management tracks: On the west coast these are already significant, will become more so as there is a recognised need for more protection of coastal settlements. Fire breaks and management tracks contribute to the effects of fragmentation (increased edge effects, barrier to of flora and fauna movement), and may lead to soil erosion and compaction, increased turbidity of waterways, weed invasion and increased passage for pest plants and animals and plant pathogens such as *Phytophthora*. Placement of fire breaks and management tracks should be sensitive to these issues.

Grazing management: The management of overabundant koala populations involve a number of methods including translocation, fertility control and habitat manipulation (protection of individual trees). On Snake Island, ground-dwelling grazers such as Hog Deer are thought to contribute to the browsing pressure on manna gum seedlings and options for their management are being investigated. The key consideration is the overall grazing

pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Phytophthora containment & hygiene measures: Containment and hygiene measures are used to minimise the spread of *Phytophthora cinnamomi*. Procedures include management (or minimization) of movement of people, vehicles, equipment and other materials from infested into uninfested sites, and may include wash-down facilities. Other considerations include road placement, movement of gravel, road grading operations, drainage and management of vehicle tracks and fire operations.

Restoration: Different restoration methods applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.2.5. Resultant Habitat Structure

Tree species: *Eucalyptus viminalis* subsp. *pyroriana*, *E. ovata*, *E. baxteri*, *Allocasuarina* spp. and *Banksia* spp.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire).

6.2.6. References

Cheal, D. (2010). *Growth stages and tolerable fire intervals for Victoria's native vegetation data sets*. Fire and Adaptive Management Report No. 84. Department of Sustainability and Environment, East Melbourne.

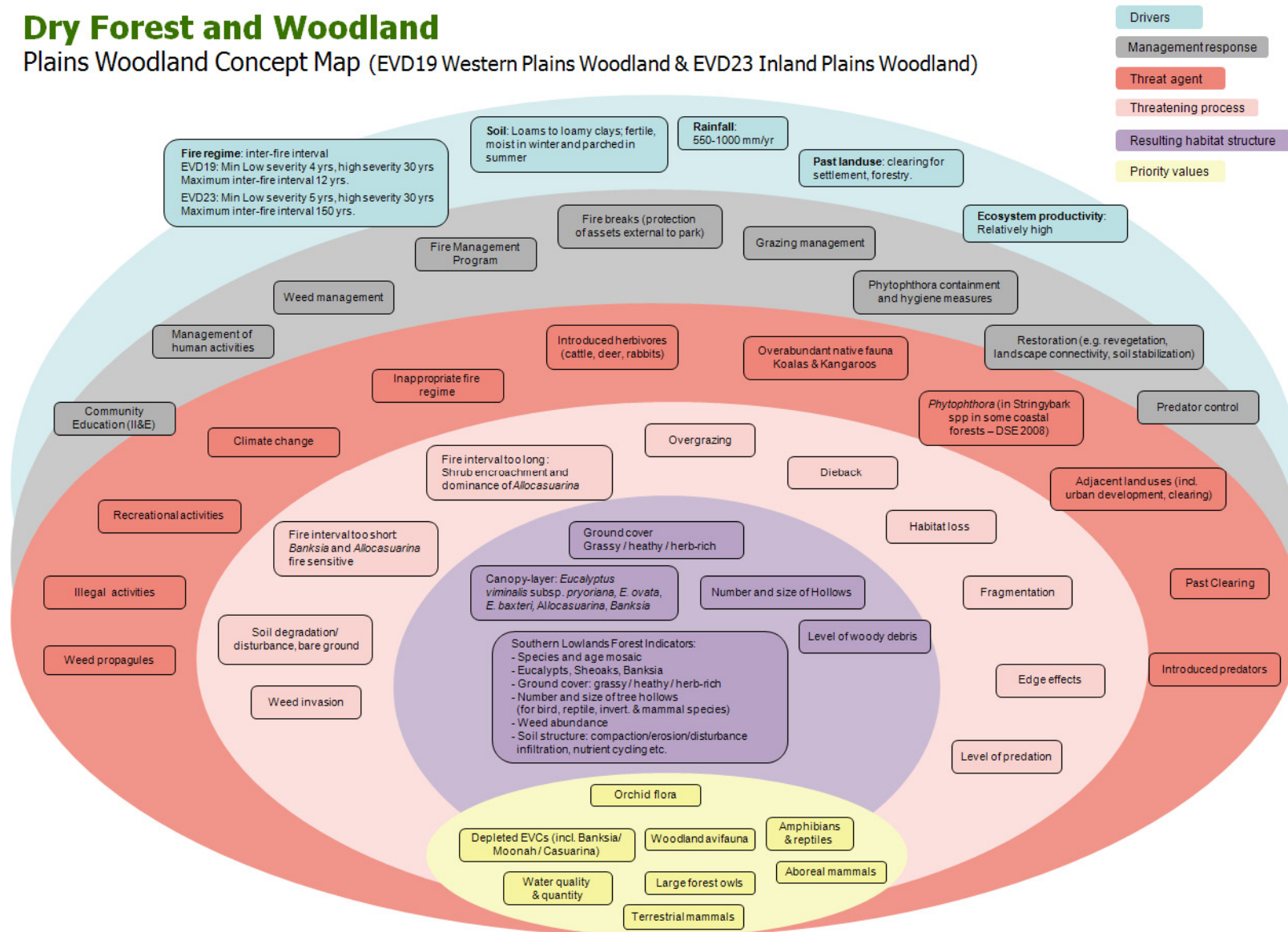
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Lunt, I.D. (1998). *Allocasuarina* (Casuarinaceae) invasion of unburnt coastal woodland at Ocean Grove, Victoria: structural changes 1971-1996. *Australian Journal of Botany* 46: 649-656.

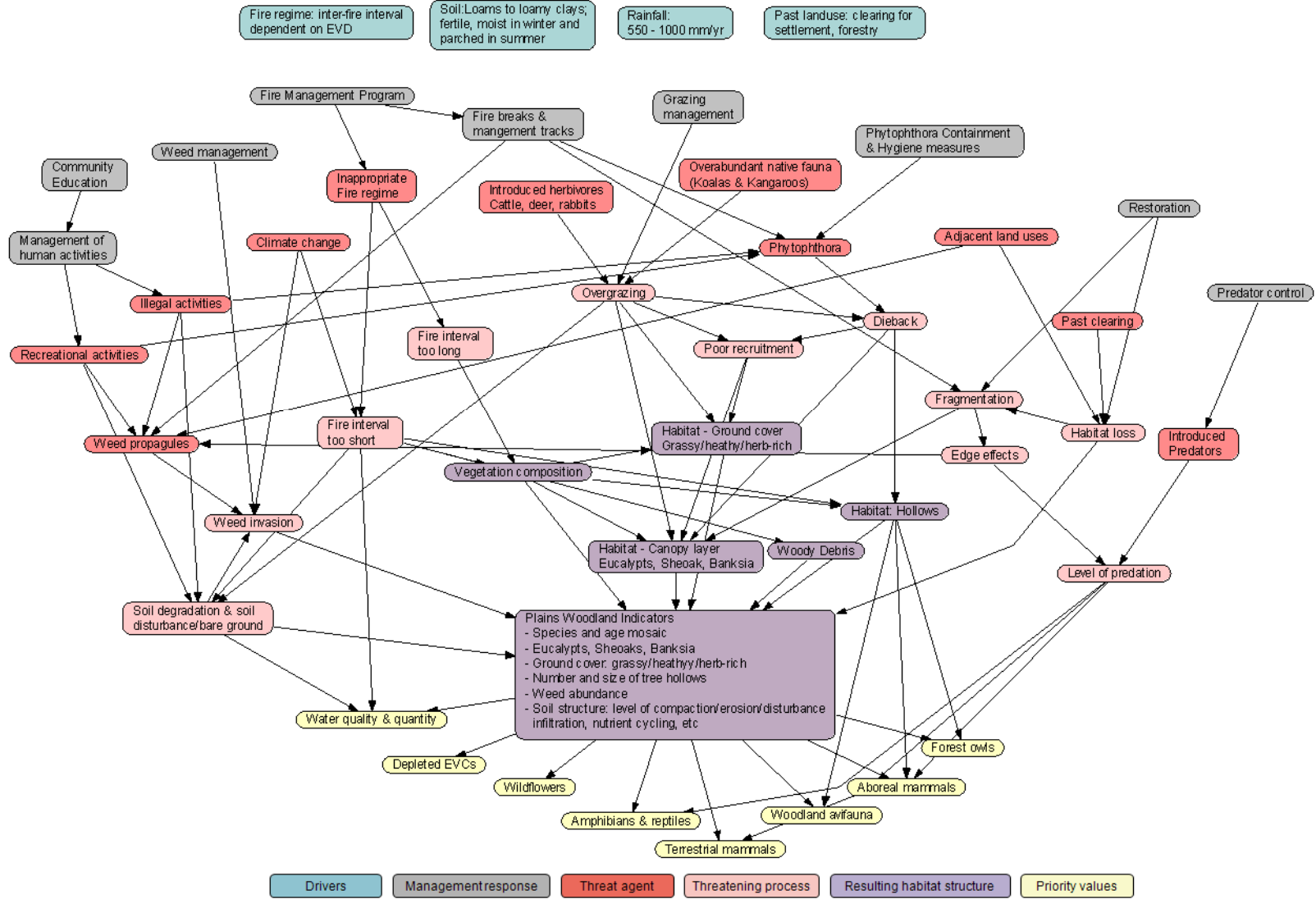
Dry Forest and Woodland

Plains Woodland Concept Map (EVD19 Western Plains Woodland & EVD23 Inland Plains Woodland)

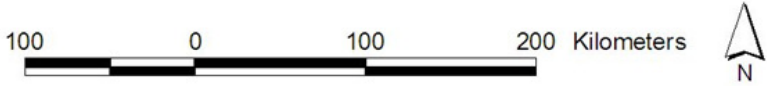
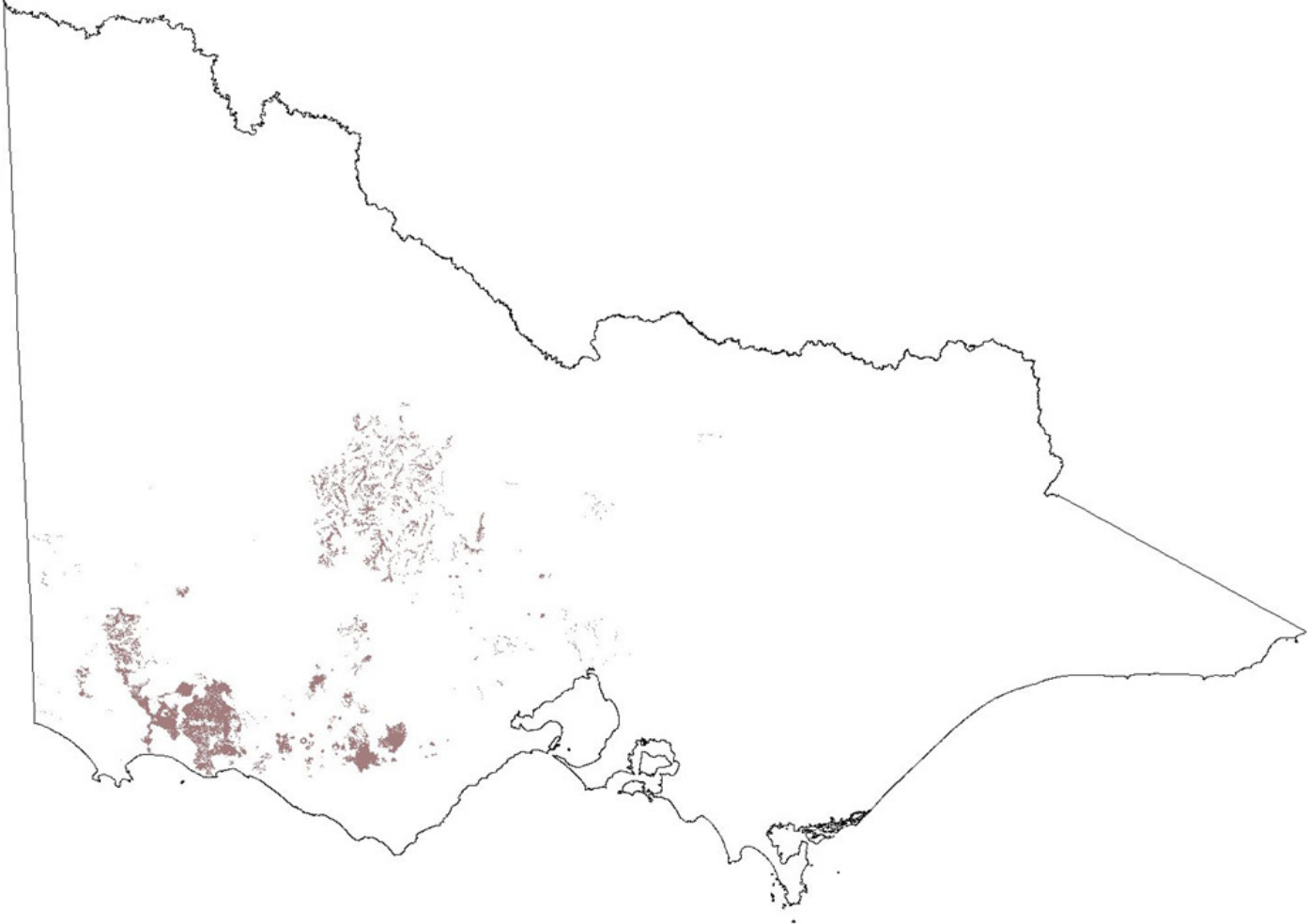


Dry Forest and Woodland

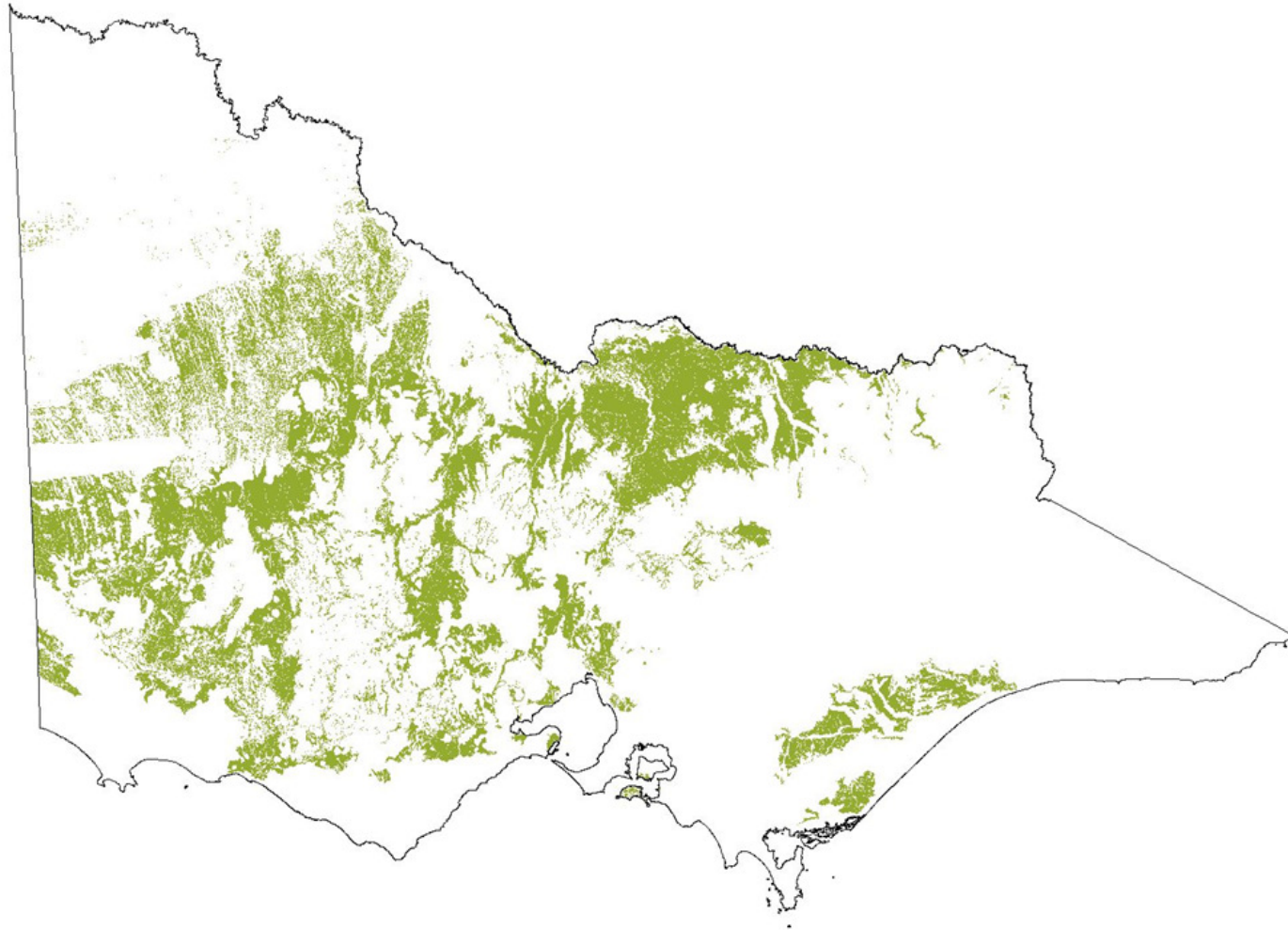
Plains Woodland Causal Model (EVD19 Western Plains Woodland & EVD23 Inland Plains Woodland)



EVD 19 Western Plains Woodland



EVD 23 Inland Plains Woodland



100 0 100 200 Kilometers



A21

6.3. Dry Forest & Woodland – Mixed Dry Forest (EVD3, 7, 8, 9, 17 & 18)

Includes EVD3 (Grassy/Heathy Dry Forest), EVD7 (Tall Mixed Forest), EVD8 (Foothills Forest), EVD9 (Forby Forest), EVD17 (Granitic Hillslopes), EVD18 (Rocky Knoll) and.

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.3.1. Drivers

Fire regime: The fire regime for this ecosystem type (Mixed Dry Forest) is not easy to summarize because of the high number of constituent EVDs. See table below for details of the maximum and minimum fire intervals for the EVDs that make up the Mixed Dry Forest ecosystem type (Cheal 2010).

| EVD | | Maximum fire interval | Min. fire interval High severity | Min. fire interval Low severity |
|-----|--------------------------|---------------------------------------|----------------------------------|---------------------------------|
| 3 | Grassy/heathy dry forest | 45 | 15 | 10 |
| 7 | Tall mixed forest | 60 | 25 | 8 |
| 8 | Foothills forest | 100 | 25 | 10 |
| 9 | Forby forest | 150 | 15 | 15 |
| 17 | Granitic Hillslopes | 90 (euc canopy) Infinite (non-euc) | 25 (euc canopy) 45 (non-euc) | 15 |
| 18 | Rocky Knoll | 80 | 20 | 12 |

Soil: Variable, includes clay-loam, sandy-loam and shallow rocky soils

Rainfall: Moderate, between an average of 550 – 1000 mm per year

Past landuse: Disturbance in this ecosystem type has been mainly from the clearing trees for grazing (sheep, horses and cattle), the sowing of exotic pasture grasses, and altered fire regimes.

Ecosystem productivity: Relatively high compared to the other *Dry Forest and Woodland* types.

6.3.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include blackberry, gorse and introduced grasses.

Recreational activities: These include the use of mountain bikes, motor bikes and cars, and hiking and camping.

Illegal activities: These include the theft of flora and fauna (e.g. orchids, herbs and parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: Climate change projections for Victoria include increased drought, reduced runoff, increased risk of bushfire and longer bushfire seasons. This is likely to lead to changes in the structure and composition of native vegetation communities, and the loss of some flora and fauna species. The most important impact of climate change on these systems is likely to be increased drought and increased fire frequency.

Inappropriate fire regime: A fire regime is inappropriate if it does not meet the requirements of the suite of species which makes up the ecosystem type. The interval between fires may be too long or too short, or fire intensity may be insufficient to release the seeds of one or more important species. An inappropriate fire regime will lead to a change in the composition and structure of native vegetation, and the loss (or reduced abundance) of dependent fauna.

Introduced herbivores: Include deer, horses, rabbits and goats.

Phytophthora: *Phytophthora cinnamomi* is a water mould that attacks the root systems of susceptible native plant species, causing plant mortality. This can change the composition and structure of native vegetation communities, and result in the loss of habitat for dependent fauna. Phytophthora infestations occur in this ecosystem type in some parks (e.g. Brisbane Ranges, Wilsons Promontory and Grampians national parks) (DSE 2008).

Past clearing: This ecosystem type was extensively cleared for agriculture, timber extraction and urban development, and as a result is highly fragmented, though there are some large relatively well-connected areas.

Adjacent landuse: Agriculture and urban development in surrounding areas are a potential source of weed propagules, and runoff containing nutrients, pesticides and herbicides. The modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Firewood collection: Firewood collection is permitted in some parks and reserves. Dry firewood and green fallen firewood may be collected from designated locations. A permit is required and there are limits on the amount that can be taken. Firewood collection reduces available habitat for ground dwelling mammals, birds, amphibians, reptiles and invertebrates.

Introduced predators: Includes foxes, cats and wild dogs.

6.3.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Bare ground provides the opportunity for the invasion and establishment of weed species. Soil disturbance and compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought are a decrease in flowering and nectar flow (particularly in eucalypts); a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire severity and frequency.

Fire too frequent (interval too short): May result in loss of species where the inter-fire interval not adequate to allow species to reach reproductive maturity and produce seed (loss of these species in the seed bank). Too frequent fire may also result in the loss of old, hollow-bearing trees, changes in vegetation composition and structure and the loss of habitat for dependent fauna.

Fire not frequent enough (interval too long): This will lead to increased dominance of shade tolerant species, and the decline and possible loss of species that require fire to regenerate (e.g. heath species in this ecosystem type). There are some EVDs in this ecosystem type where fire may not be required to maintain the typical species composition (e.g. EVD9 Forby Forest, non-eucalypt component of EVD17 Granitic Hillslopes).

Overgrazing: This may be due to introduced herbivores (deer and rabbits) or overabundant native herbivores (koalas and kangaroos). Overgrazing leads to changes in vegetation structure and composition, and the loss habitat for dependent fauna.

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. These include insect attack (may be accompanied by a decrease in insectivorous birds), overabundant herbivores (e.g. koalas), changes to microclimate caused by edge effects (e.g. changes to wind and radiation fluxes), soil

compaction, drought, salinity, nutrient enrichment, disease (e.g. Phytophthora) and/or altered hydrology. Stressed trees are generally more susceptible to the effects of dieback.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of this ecosystem type. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type is highly fragmented, though there do exist some large relatively well-connected tracts. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance.

Removal of woody debris: Woody debris provides habitat and food sources. It is removed as a part of firewood collection and with fire. Woody debris comes from large trees dropping branches, and takes longer to build up in low productivity forests.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.3.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals. Prescribed burning is common practice in this ecosystem type.

Fire breaks and management tracks: Fire breaks and management tracks contribute to the effects of fragmentation (increased edge effects, barrier to of flora and fauna movement), and may lead to soil erosion and compaction, increased turbidity of waterways, weed invasion and increased passage for pest plants and animals and plant pathogens such as *Phytophthora*. Placement of fire breaks and management tracks should be sensitive to these issues.

Grazing Management: Grazing management may target introduced herbivores (e.g. rabbits) and/or overabundant native herbivores (kangaroos and koalas). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Phytophthora containment & hygiene measures: Containment and hygiene measures are used to minimise the spread of *Phytophthora cinnamomi*. Procedures include management (or minimization) of movement of people, vehicles, equipment and other materials from infested into uninfested sites, and may include wash-down facilities. Other considerations include road placement, movement of gravel, road grading operations, drainage and management of vehicle tracks and fire operations.

Restoration: Different restoration methods applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.3.5. Resultant Habitat Structure

Tree species: Peppermints (*E. radiata*, *E. dives*, *E. robertsonii*), Red and White Stringybark (*E. Macrorhyncha*, *E. globoidea*), Messmate (*E. obliqua*), Red and Long-leaf Box (*E. polyanthemos*, *E. goniocalyx*), Manna gum (*E. viminalis*), Candlebark (*E. rubida*), and Mountain Grey-gum (*E. cypellocarpa*)

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire).

6.3.6. References

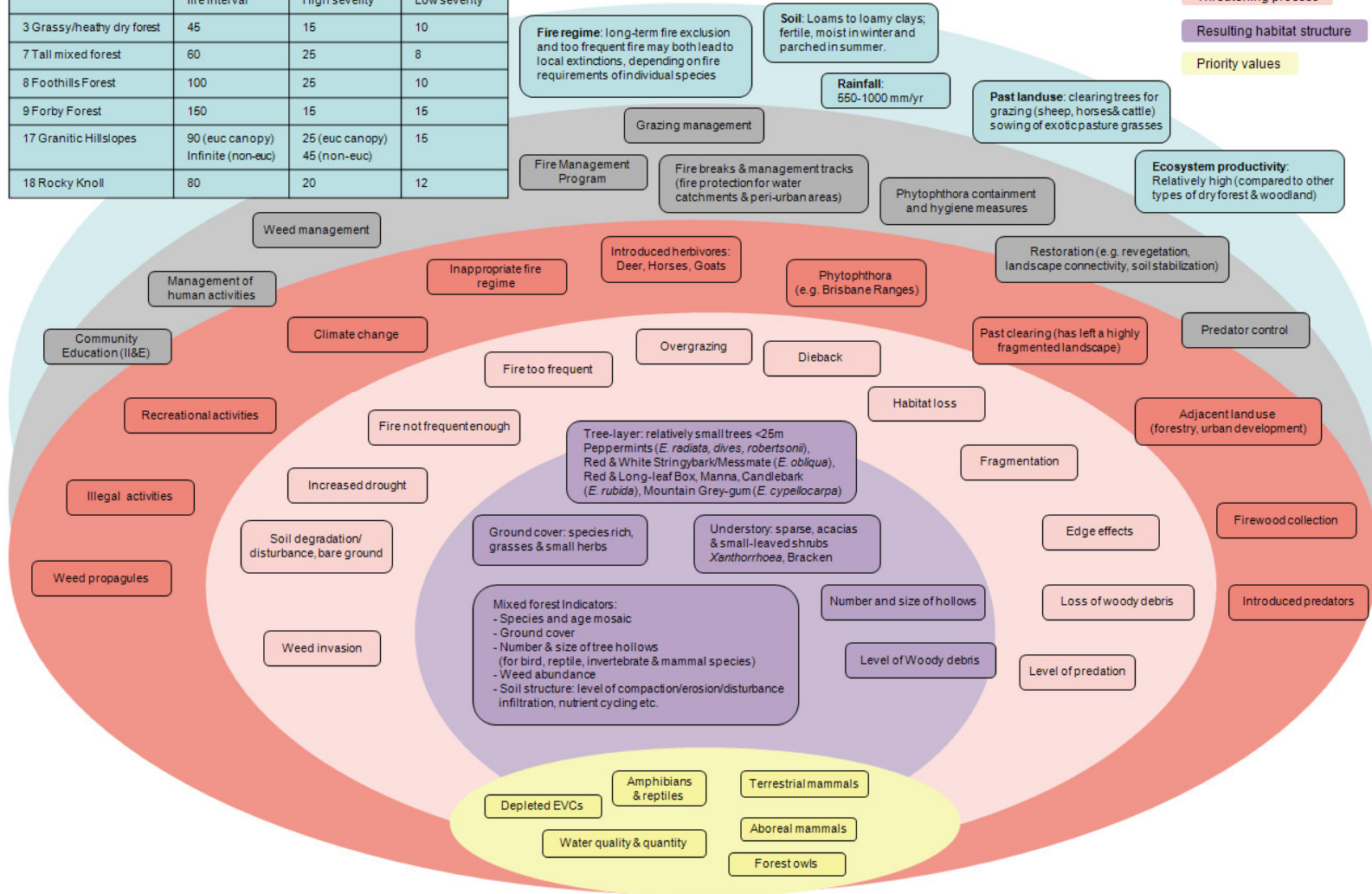
Cheal, D. (2010). *Growth stages and tolerable fire intervals for Victoria's native vegetation data sets*. Fire and Adaptive Management Report No. 84. Department of Sustainability and Environment, East Melbourne.

DSE (2008). Victoria's Public Land *Phytophthora cinnamomi* Management Strategy. Department of Sustainability and Environment, Melbourne.

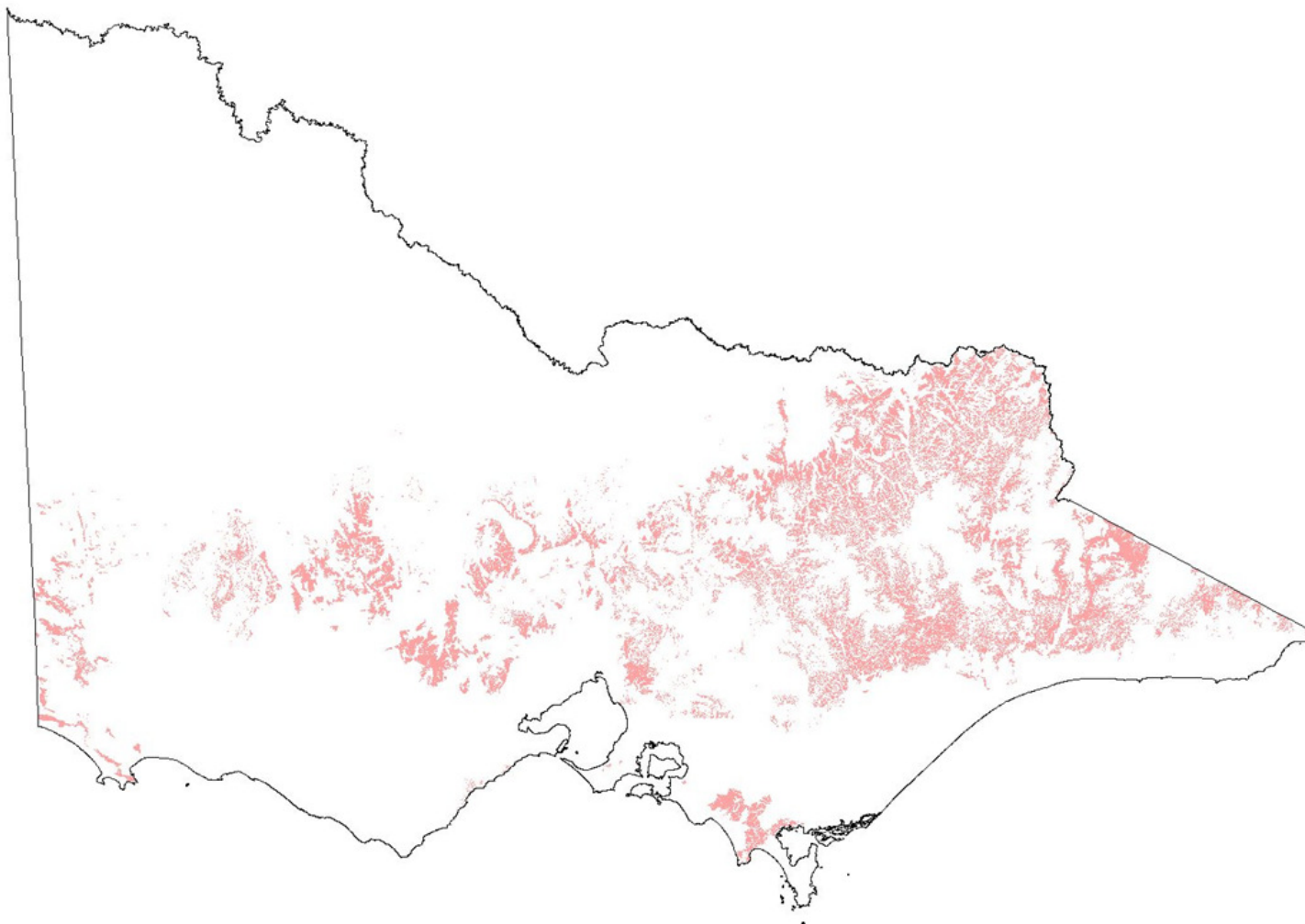
Dry Forest and Woodland

Mixed Dry Forest Concept Map (includes EVD3, 7, 8, 9, 17, 18)

| EVD | Maximum fire interval | Min fire interval High severity | Min fire interval Low severity |
|-----------------------------|---------------------------------------|---------------------------------|--------------------------------|
| 3 Grassy/healthy dry forest | 45 | 15 | 10 |
| 7 Tall mixed forest | 60 | 25 | 8 |
| 8 Foothills Forest | 100 | 25 | 10 |
| 9 Forby Forest | 150 | 15 | 15 |
| 17 Granitic Hillslopes | 90 (euc canopy) Infinite (non-euc) | 25 (euc canopy) 45 (non-euc) | 15 |
| 18 Rocky Knoll | 80 | 20 | 12 |

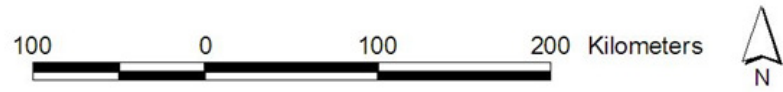
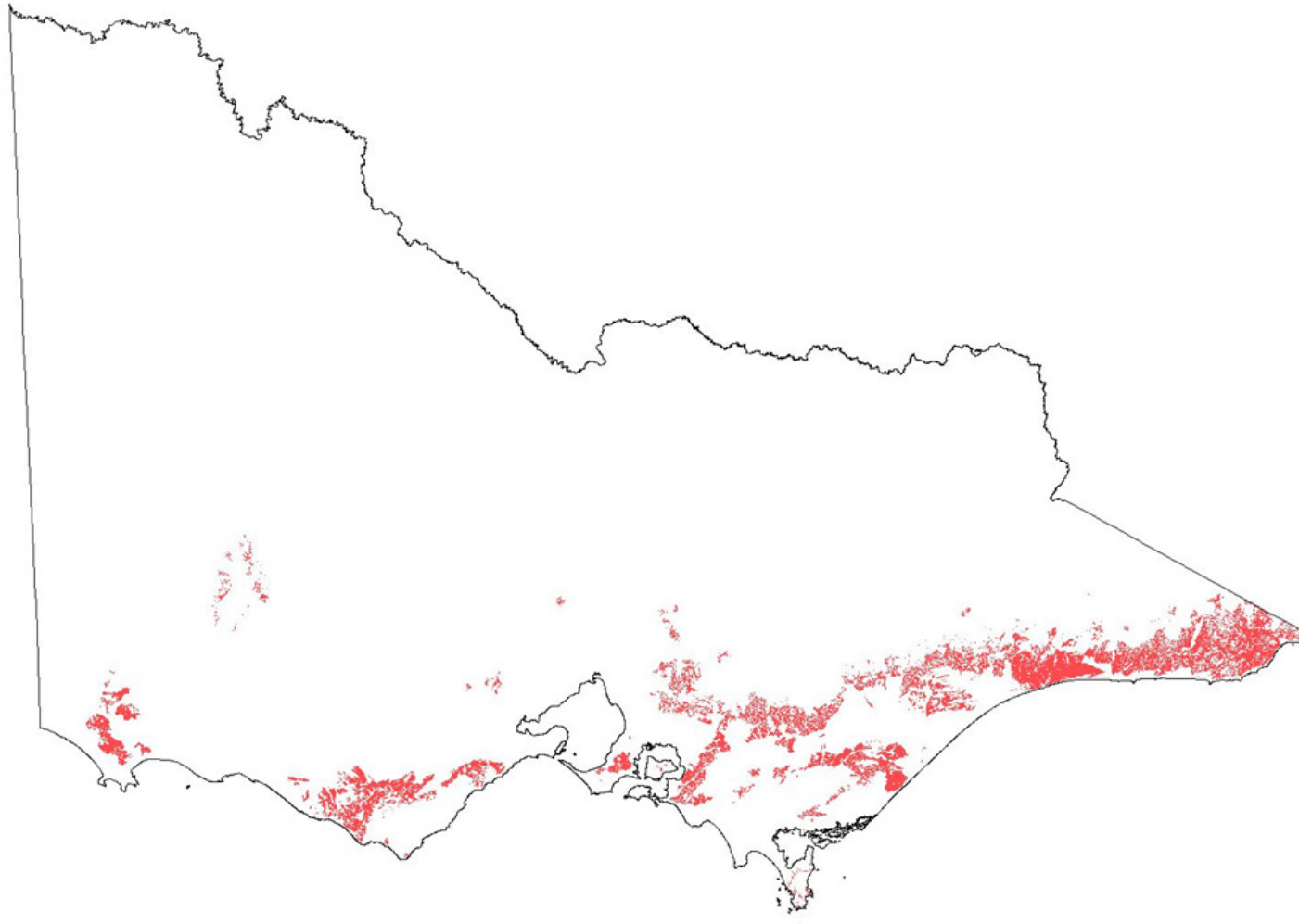


EVD 3 Grassy/Heathy Dry Forest



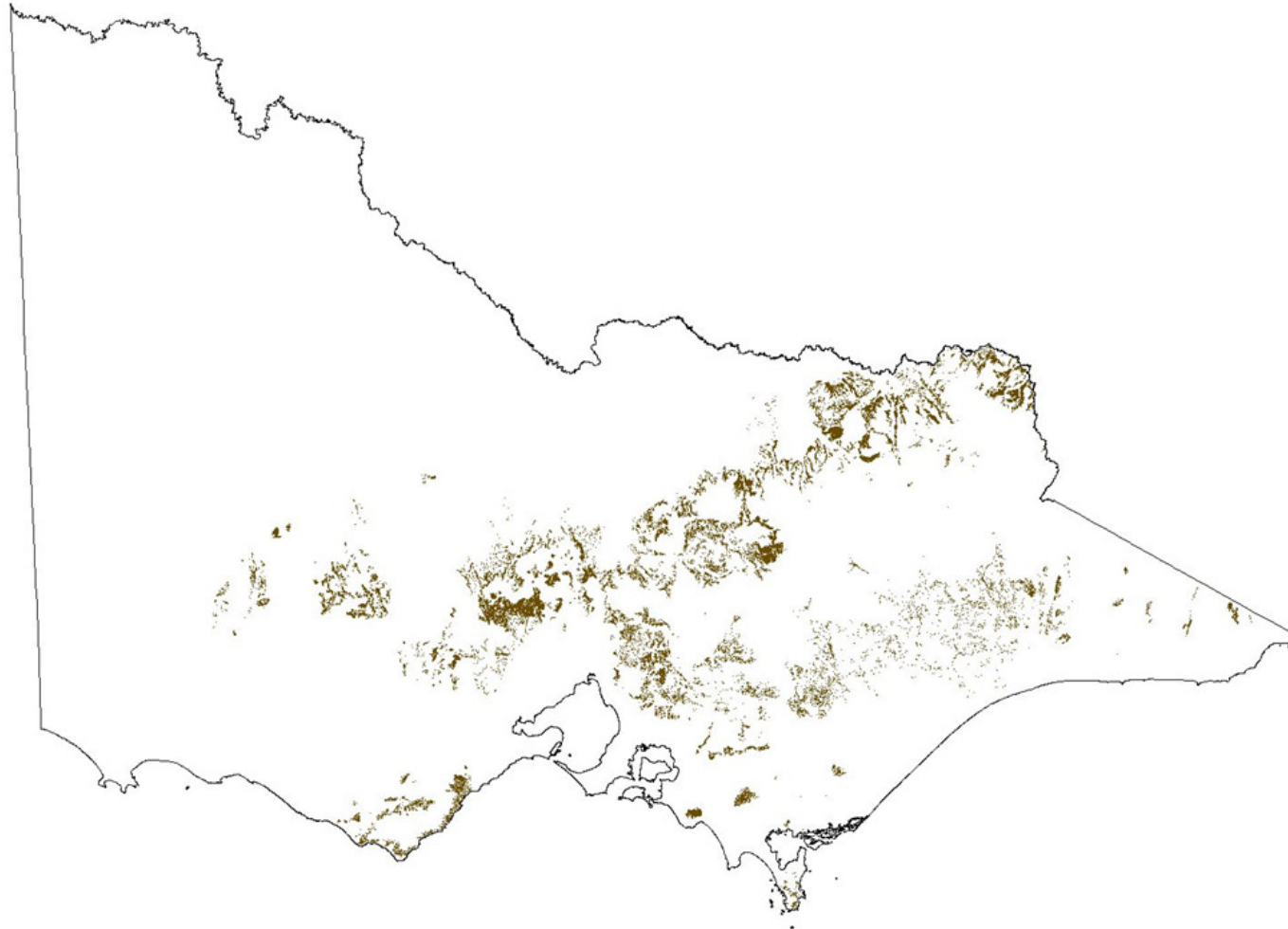
A32

EVD 7 Tall Mixed Forest (eastern)



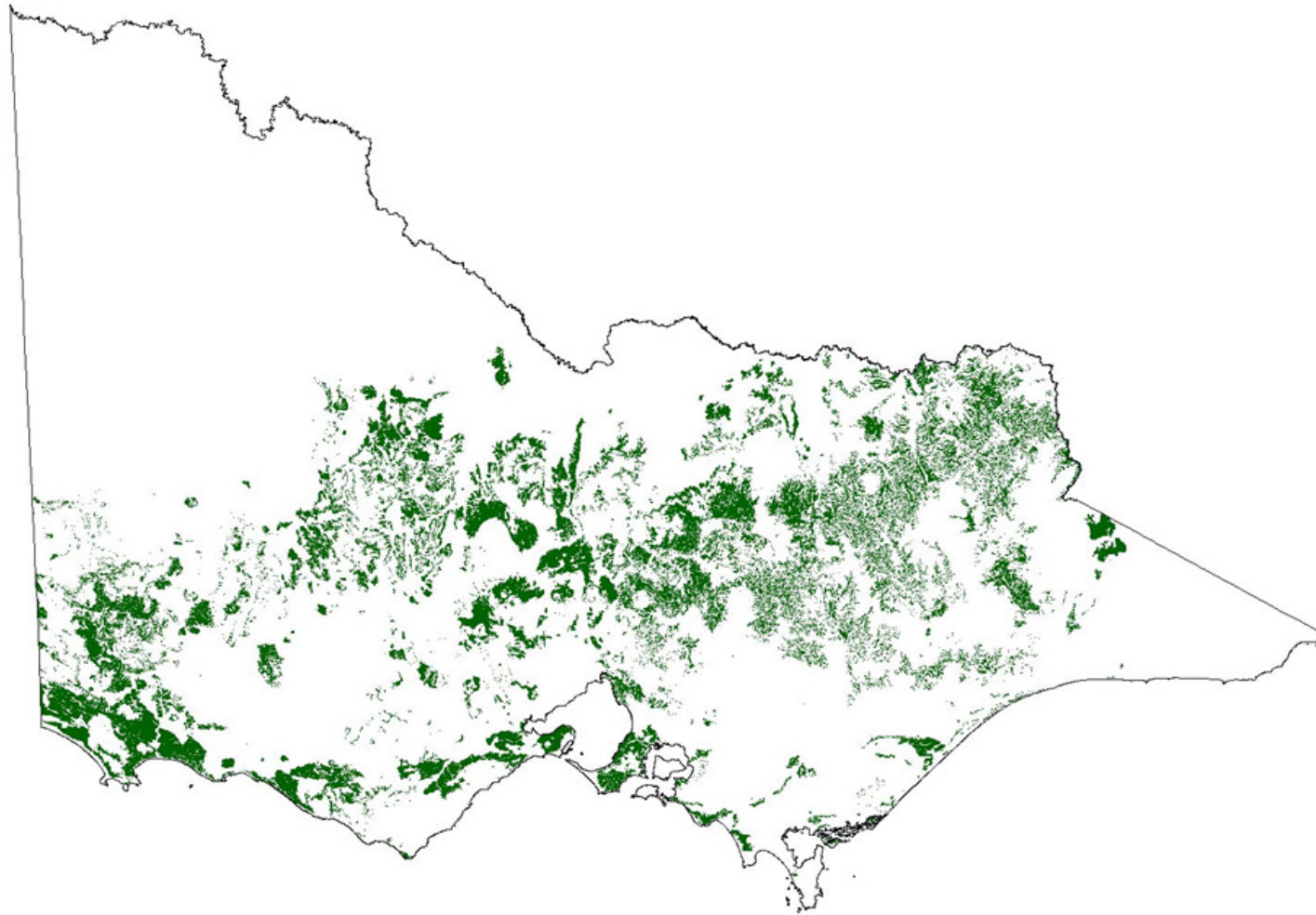
A33

EVD 8 Foothills Forest



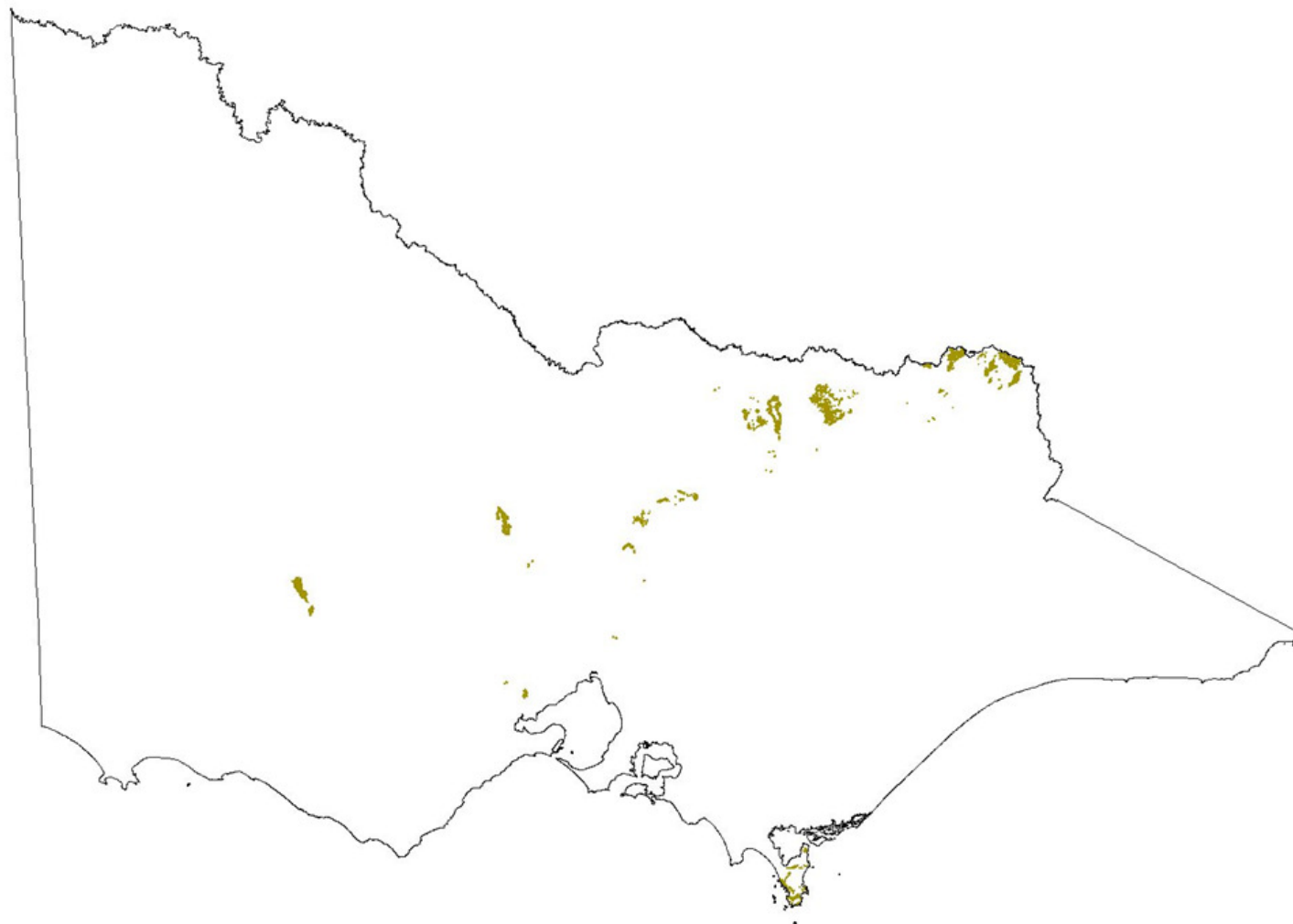
A34

EVD 9 Forby Forest



A35

EVD 17 Granitic Hillslopes

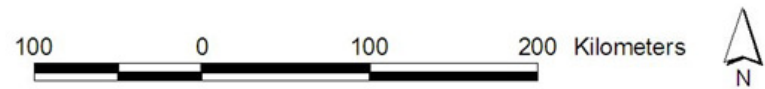
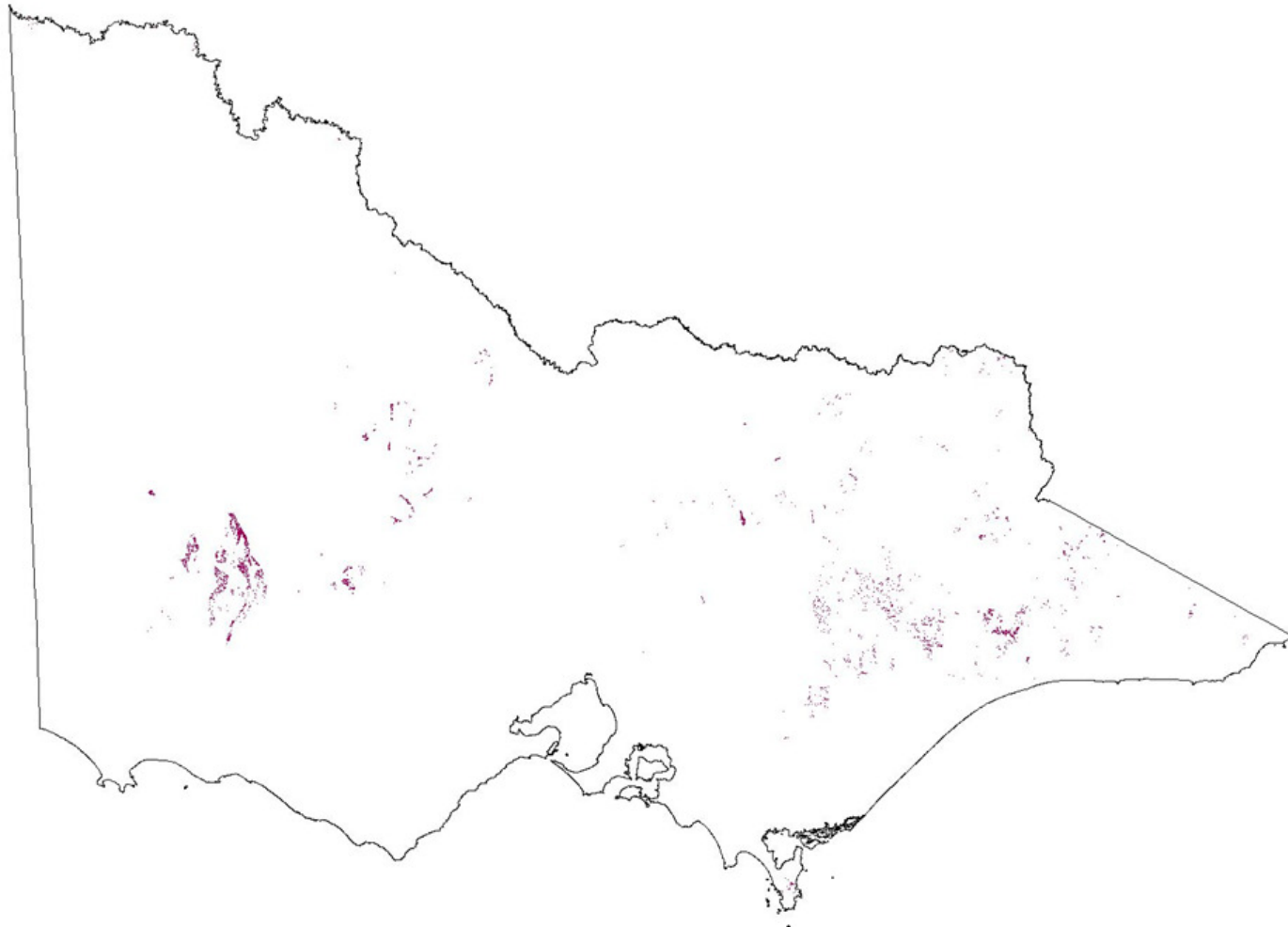


100 0 100 200 Kilometers



A36

EVD 18 Rocky Knoll



A37

6.4. Dry Forest & Woodland – Semi-arid Woodland (EVD 22)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.4.1. Drivers

Fire regime: Low fuel loads, fires naturally rare, important structural species take many years to recover from fire (Cheal 2010). Minimum fire interval for low severity fires is 20 years, and for high severity fires is 80 years. There is no upper limit to the fire interval, post-fire regeneration occur in few (if any) species, and some species are extremely fire sensitive (e.g. Slender Cypress-pine *Callitris gracilis* is killed by fire) (Cheal 2010).

Soil: Soils potentially very mobile, biological soils crusts are very important in protecting soils from erosion.

Rainfall: Low rainfall, semi-arid environment, rainfall varies between about 250mm to 450 mm per year, with high inter-annual variability.

Past landuse: This ecosystem type was cleared for agriculture (wheat and sheep farming) and urban development.

Ecosystem productivity: Low, recovery is generally very slow, woody debris is generated very slowly.

6.4.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include Red Brome, Mediterranean Turnip, Cat's-ear, Horehound and Sow Thistle.

Recreational activities: These include the use of mountain bikes, motor bikes and cars, and hiking and camping.

Illegal activities: These include the theft of flora and fauna (e.g. parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and/or the biological soil crust, and cause soil compaction and erosion.

Climate change: Climate change projections for Victoria include increased drought, reduced runoff, increased risk of bushfire and longer bushfire seasons. This is likely to lead to changes in the structure and composition of native vegetation communities, and the loss of some flora and fauna species. The most important impact of climate change on these systems is likely to be increased drought, which will impact on reproduction and recruitment. Climate change may also increase fire frequency and may result in out-of-season fires.

Inappropriate fire regime: Fire too frequent (intervals less than 20 years for low severity fire and less than 80 years for high severity fire), some species in these systems are extremely sensitive to fire.

Overabundant native herbivores: Over-abundant native fauna (may include Western Grey Kangaroos and Red Kangaroos). Probably rely on the water supply in adjacent land (farm dams etc).

Introduced herbivores: Include rabbits and goats.

Past clearing: This ecosystem type was extensively cleared for agriculture (wheat and sheep) and urban development and is highly fragmented.

Adjacent landuse: May be a source of weed propagules and nutrients, and provide a water and food source for Western Grey Kangaroos and Red Kangaroos.

Firewood collection: Firewood collection reduces available habitat for ground dwelling mammals, birds, reptiles and invertebrates, woody debris is generated very slowly in this ecosystem type.

Introduced predators: Includes foxes, cats and wild dogs.

6.4.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Increased erosion and movement of soils, degradation of biological soil crust: Soils in semi-arid woodlands are potentially very mobile, and as a result biological soils crusts are very important in protecting these soils from erosion. Biological soil crusts also regulate the flow of water into soils and provide sites for the establishment and survival of seedlings (Eldridge 2000). Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation and biological soil crusts in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Bare ground provides the opportunity for the invasion and establishment of weed species. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Fire too frequent (interval too short): Intervals less than 20 years for low severity fires and less than 80 years for high severity fires. May result in loss of species where the inter-fire interval not adequate to allow species to reach reproductive maturity and produce seed (loss of these species in the seed bank). Also may result in changes in vegetation composition and structure, and impacts on fauna habitat (hollows and woody debris). White Cypress-pine is

extremely fire sensitive and seedlings and mature trees are easily killed by a single fire event.

Overgrazing: This ecosystem type is sensitive to grazing, and post-grazing regeneration is poor. Seedlings may require protection (fenced exclosures) from rabbit and kangaroo grazing. Overgrazing also contributes to soil erosion and compaction, conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground), and may result in the loss habitat for dependent fauna.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. This is likely to impact on the rate of successful recruitment and the frequency of reproductive events for tree species in this ecosystem type (see below), leading to a decrease in vegetation cover. Biological soil crusts may also be affected by drought due to a decrease in the number of days that are suitable for growth, which is likely to make them more vulnerable to disturbance as they will be slower to recover.

Failure to reproduce: Some of the tree species that make up this ecosystem type may require a succession of years with above average rainfall before they will reproduce; if climate change leads to increased drought these conditions will become less frequent.

Poor recruitment: Poor recruitment can result from the loss of mature individuals (from natural or human causes), a decrease in conditions suitable for reproduction, low germination or seedling production and/or seedling mortality.

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. These include insect attack (may be accompanied by a decrease in insectivorous birds), overabundant herbivores, changes to microclimate caused by edge effects (e.g. changes to wind and radiation fluxes), soil compaction, drought, salinity, nutrient enrichment, disease and/or altered hydrology. Stressed trees are generally more susceptible to the effects of dieback. Dieback may result in decreased reproductive effort, and may eventually lead to tree death.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, dust (and other particulate deposition), insect attack, predator incursions, nutrient enrichment and soil disturbance. Biota at or near the edge of an area of remnant vegetation may be affected by changes in the microclimate (e.g. fluxes of wind, radiation and water) which influence humidity and soil moisture. This can contribute to dieback and subsequent stand thinning.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of this ecosystem type. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. Semi-arid woodlands were extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Loss of woody debris: This is important in semi-arid woodlands as they are low productivity systems and generate woody debris very slowly. Woody debris provides habitat and food sources. It is removed as a part of firewood collection and with fire.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.4.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals. Fire management in this ecosystem type is focused on suppression and the identification of significant biota that requires protection from fire.

Grazing management: Grazing management may target introduced herbivores (rabbits and goats) and/or overabundant native herbivores (kangaroos). The key consideration is the

overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora). In this ecosystem type grazing management is required in areas where grazing pressure is sufficient to suppress the regeneration of woody vegetation. The increased availability of water in these systems has allowed kangaroo populations to be sustained at artificially high densities during dry periods. Diversity and abundance of native plant species may need to be monitored to determine the carrying capacity for kangaroos. Limiting access to water (fencing or decommissioning water sources within parks, fencing at park boundary to limit access to water and pasture) helps to control goat and kangaroo populations. Kangaroo populations are also controlled by culling. Rabbit management can include poisoning, ripping, fumigation, shooting and biological control.

Restoration: Different restoration methods applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.4.5. Resultant Habitat Structure

Tree species: Sparse canopy (10-20m tall) of *Callitris gracilis* (Slender Cypress-pine) or *Allocasuarina luehmannii* (Buloke) or both; sometimes *Callitris glaucophylla* (White Cypress-pine) or *Casuarina pauper* (Belah).

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire).

6.4.6. References

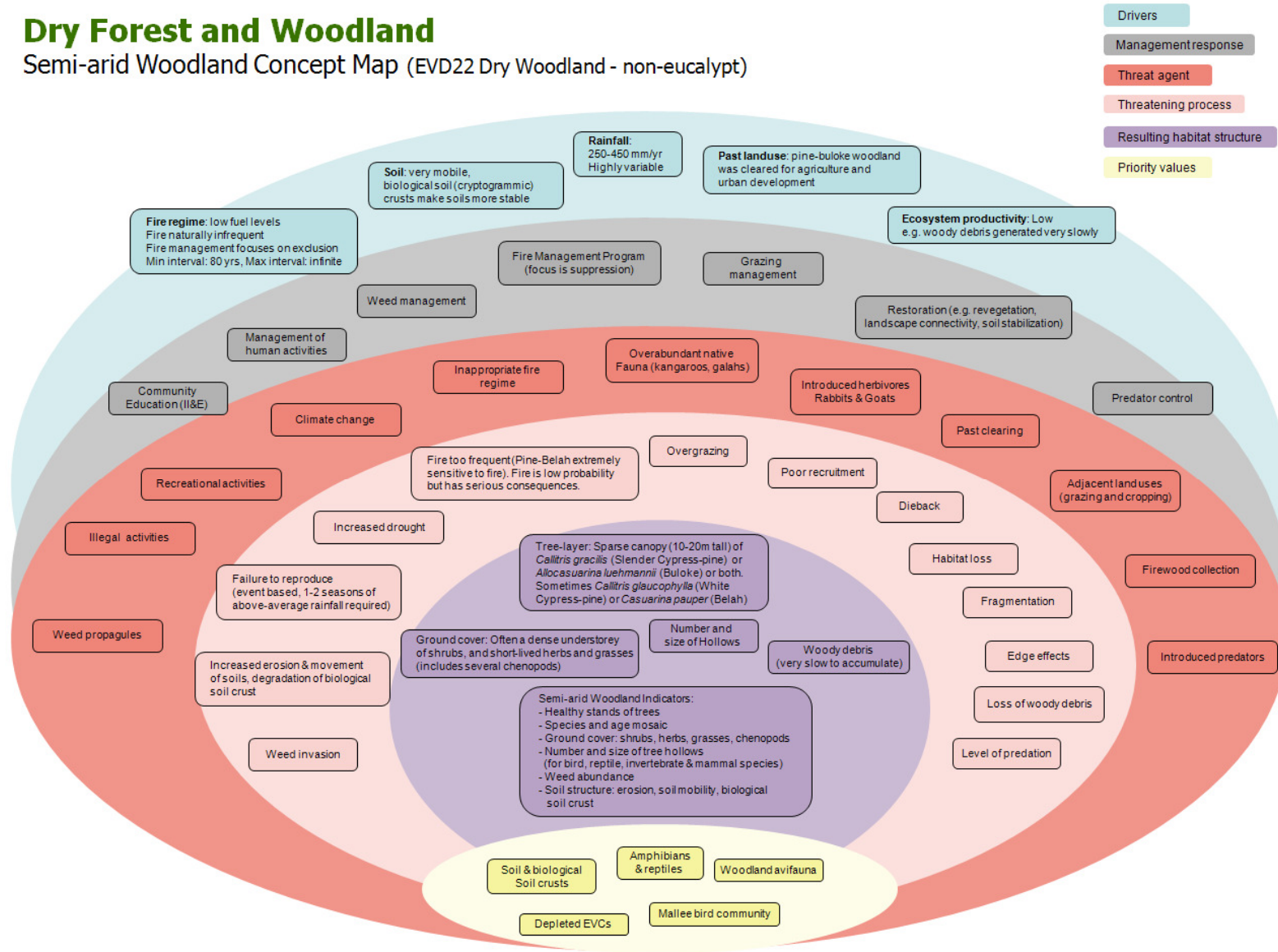
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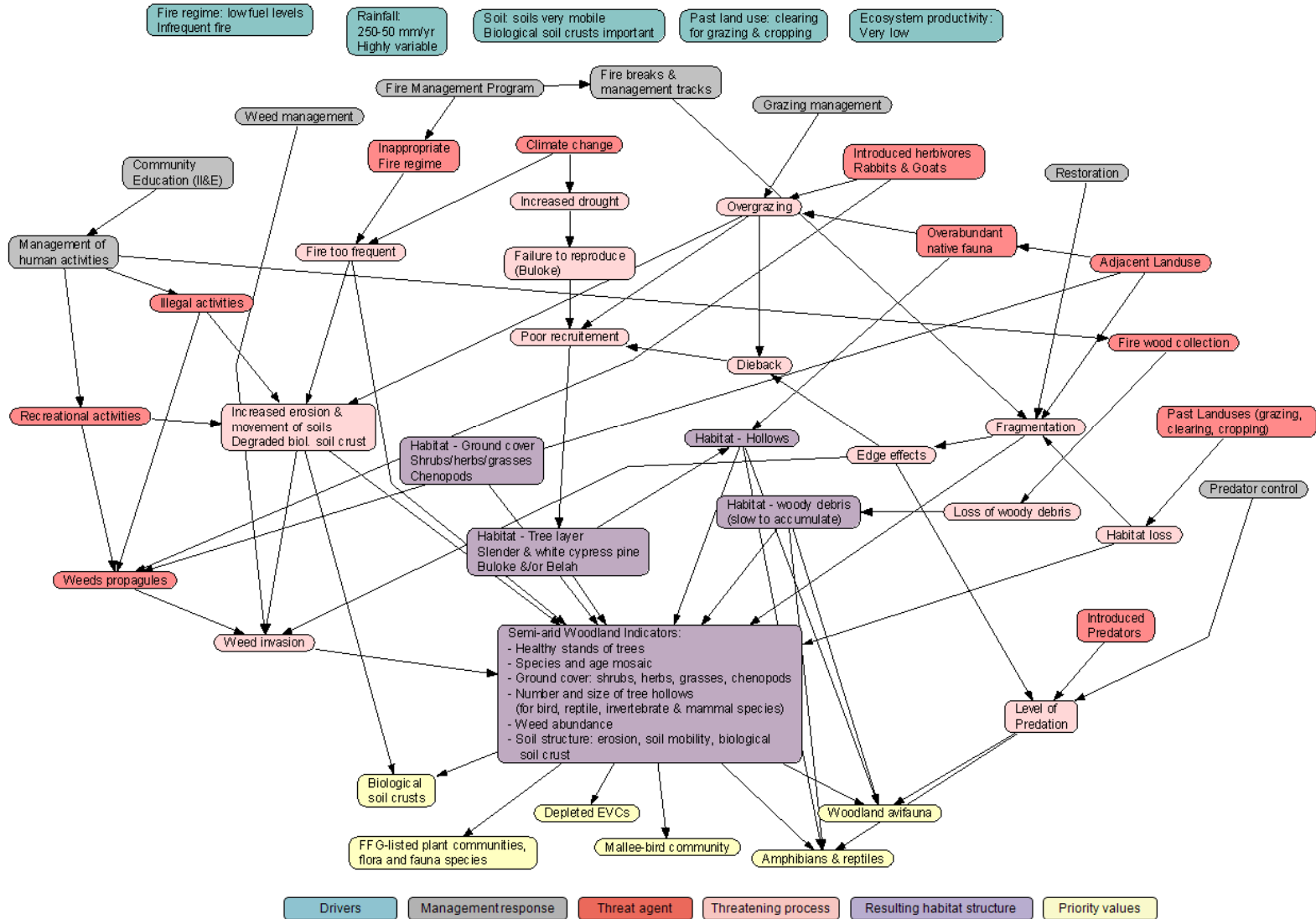
Dry Forest and Woodland

Semi-arid Woodland Concept Map (EVD22 Dry Woodland - non-eucalypt)

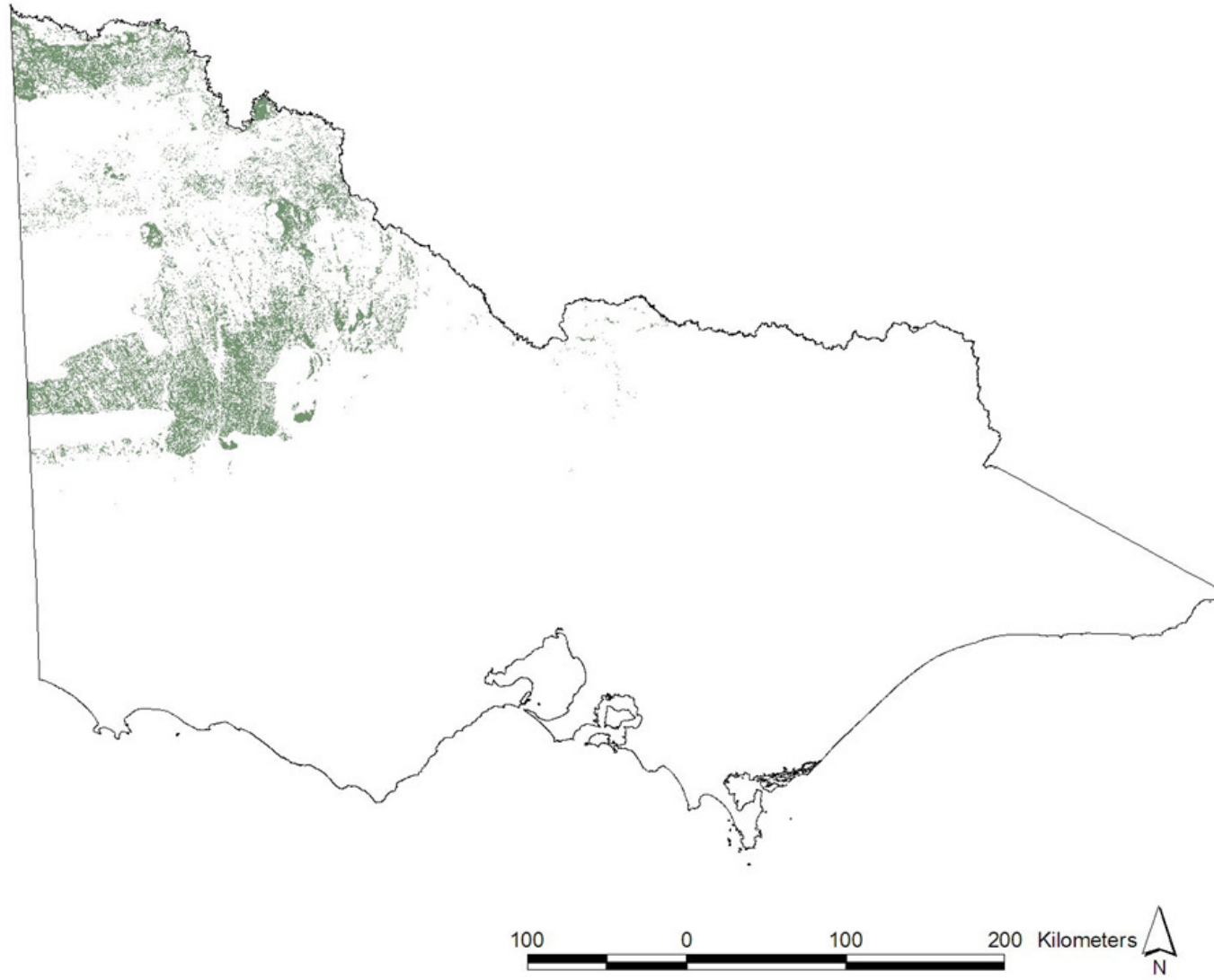


Dry Forest and Woodland

Semi-arid Woodland Causal Model (EVD22 Dry Woodland - non-eucalypt)



EVD 22 Dry Woodland (non-Eucalypt)



A47

6.5. Wet Forest & Rainforest – Damp & Wet Forest (EVD10 & EVD12)

This includes EVD10 (Moist Forest) and EVD12 (Tall Mist Forest).

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are split up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.5.1. Drivers

Fire regime: Dependent on which EVD is being considered.

EVD10 Moist Forest (Damp Sclerophyll Forest): Minimum fire interval for both low and high severity fire is **25** years; the maximum fire interval is **150** years (Cheal 2010).

EVD12 Tall Mist Forest (Wet Sclerophyll Forest): Minimum fire interval for both low and high severity fire is **80** years; the maximum fire interval is **150** years (Cheal 2010).

Soil: deep loamy soils with a deep litter layer. High rainfall and steep slopes make this ecosystem type a high erosion risk.

Rainfall:

Damp Sclerophyll Forest: annual average between 750-1200 mm per year

Wet Sclerophyll Forest: annual average greater than 1100 mm per year

Elevation:

Damp Sclerophyll Forest 200-1100 metres

Wet Sclerophyll Forest 600-1300 metres

Past landuse: Clearing for agriculture, urban development and forestry.

Ecosystem productivity: Productivity in this ecosystem type is relatively high, includes very large, fast growing tree species.

6.5.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include Blackberry, English Ivy, Holly, English Broom, Gorse, Sweet Pittosporum (in areas where it is not indigenous), Pine wildings, Ragwort, introduced grasses and thistles. Weed species in this ecosystem type are generally restricted to disturbed areas (roads, visitor sites and walking tracks), but local infestations may be severe.

Recreational activities: These include the use of mountain bikes, motor bikes and cars (includes four-wheel driving), and horse riding, hiking and camping.

Illegal activities: These include the theft of flora and fauna (e.g. ferns, parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: Climate change projections for Victoria include increased drought, reduced runoff, increased risk of bushfire and longer bushfire seasons. This is likely to lead to changes in the structure and composition of native vegetation communities, and the loss of

some flora and fauna species. The most important impact of climate change on these systems is likely to be increased drought and increased fire danger. This ecosystem type is less prone to fire than the dry forests and woodlands, however, increased temperatures and decreased runoff may result in an increase in fire frequency.

Inappropriate fire regime: A fire regime is inappropriate if it does not meet the requirements of the suite of species which makes up the ecosystem type. The interval between fires may be too long or too short, or fire intensity may be insufficient to release the seeds of one or more important species. An inappropriate fire regime will lead to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna.

Inappropriate fire management & suppression methods: These can include the creation of fire breaks/access tracks in vegetation types that are sensitive to disturbance (where natural recovery is unlikely and/or restoration is difficult), or in areas that may already be highly fragmented. It may also include the use of fire retardants and wetting agents and foams. The impacts of fire breaks and access tracks include habitat loss and fragmentation (increasing edge effects), soil erosion (increased turbidity and sedimentation of waterways), soil compaction (from the use of heavy machinery), weed invasion, and the movement of plant pathogens such as *Phytophthora* and Myrtle Wilt. They create a barrier to migration for native fauna and increased passage way for introduced pest plants and animals.

Introduced herbivores: Include deer and goats.

Phytophthora: *Phytophthora cinnamomi* is a water mould that attacks the root systems of susceptible native plant species, causing plant mortality. This can change the composition and structure of native vegetation communities, and result in the loss of habitat for dependent fauna. *Phytophthora* infestations occur in this ecosystem type in some parks (e.g. Great Otway National Park).

Past clearing: Clearing for agriculture and urban development.

Adjacent landuse: Agriculture and urban development in surrounding areas are a potential source of weed propagules, and runoff containing nutrients, pesticides and herbicides. The modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Introduced predators: Includes foxes, cats and wild dogs.

6.5.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. High rainfall and steep slopes make this ecosystem type a high erosion risk. Road and infrastructure construction, vegetation removal and recreational activities (e.g. walking and horse riding) can increase bare ground the potential for soil erosion. Car parks and picnic areas are potential sites for soil compaction and runoff; roads and tracks are a potential source of sediment which degrades water quality. Bare ground also provides the opportunity for the invasion and establishment of weed plant species.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought are a decrease in flowering and nectar flow (particularly in eucalypts); a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire severity and frequency.

Fire too frequent (interval too short): May result in loss of species where the inter-fire interval is not adequate to allow species to reach reproductive maturity and produce seed (loss of these species in the seed bank). This may result in changes in vegetation composition and structure, and loss of habitat for dependent fauna. Will also result in the loss of old, hollow-bearing trees (take >100 years to form) and a reduction in woody debris. In damp forest frequent fire may lead to the dominance of bracken (*Pteridium aquilinum* var *esculentum*).

Fire not frequent enough (Fire interval too long): If the interval between fires is too long wet forest eucalypt species can be replaced prematurely (in terms of potential life span) by rainforest species. In the absence of fire, mid-storey rainforest trees and shrubs become more common (these tend to be fire sensitive and shade tolerant); and there is an accumulation of soil surface litter which creates conditions more suitable to rainforest species (Close et al. 2009).

Overgrazing: Goats and deer are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground).

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. In this ecosystem type causes includes insect attack (e.g. Psyllids), which may be accompanied by a decrease in insectivorous birds, changes to microclimate caused by edge effects, soil compaction, nutrient enrichment, disease (e.g. Phytophthora) and/or altered hydrology. Stressed trees are generally more susceptible to the effects of dieback.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of this ecosystem type. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss and fragmentation.

Fragmentation: The clearing of native vegetation in this ecosystem type has resulted in the creation of isolated patches (or fragments) of habitat; though there are some large relatively well-connected areas. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance. Biota at or near the edge of an area of remnant vegetation may be affected by changes in the microclimate (e.g. fluxes of wind, radiation and water) which influence humidity and soil moisture. This can contribute to dieback and subsequent stand thinning.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.5.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and

biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Grazing management: Grazing management in this ecosystem type would target introduced herbivores (goats and deer). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Phytophthora containment & hygiene measures: Containment and hygiene measures are used to minimise the spread of *Phytophthora cinnamomi*. Procedures include management (or minimization) of movement of people, vehicles, equipment and other materials from infested into uninfested sites, and may include wash-down facilities. Other considerations include road placement, movement of gravel, road grading operations, drainage and management of vehicle tracks and fire operations.

Restoration: Different restoration methods applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat, and to rehabilitate fire breaks and management tracks. Specific actions may be taken to stabilize soil in actively eroding areas.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.5.5. Resultant Habitat Structure

Tree species: Mountain Ash (*E. regnans*), Messmate (*E. obliqua*), Alpine Ash (*E. delegatensis*), Shining Gum (*E. nitens*), Mountain Grey-gum (*E. cypellocarpa*) and Narrow-leafed Peppermint (*E. radiata*)

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire). The level of coarse woody debris in this ecosystem type is naturally very high, as the systems have relatively high productivity.

6.5.6. References

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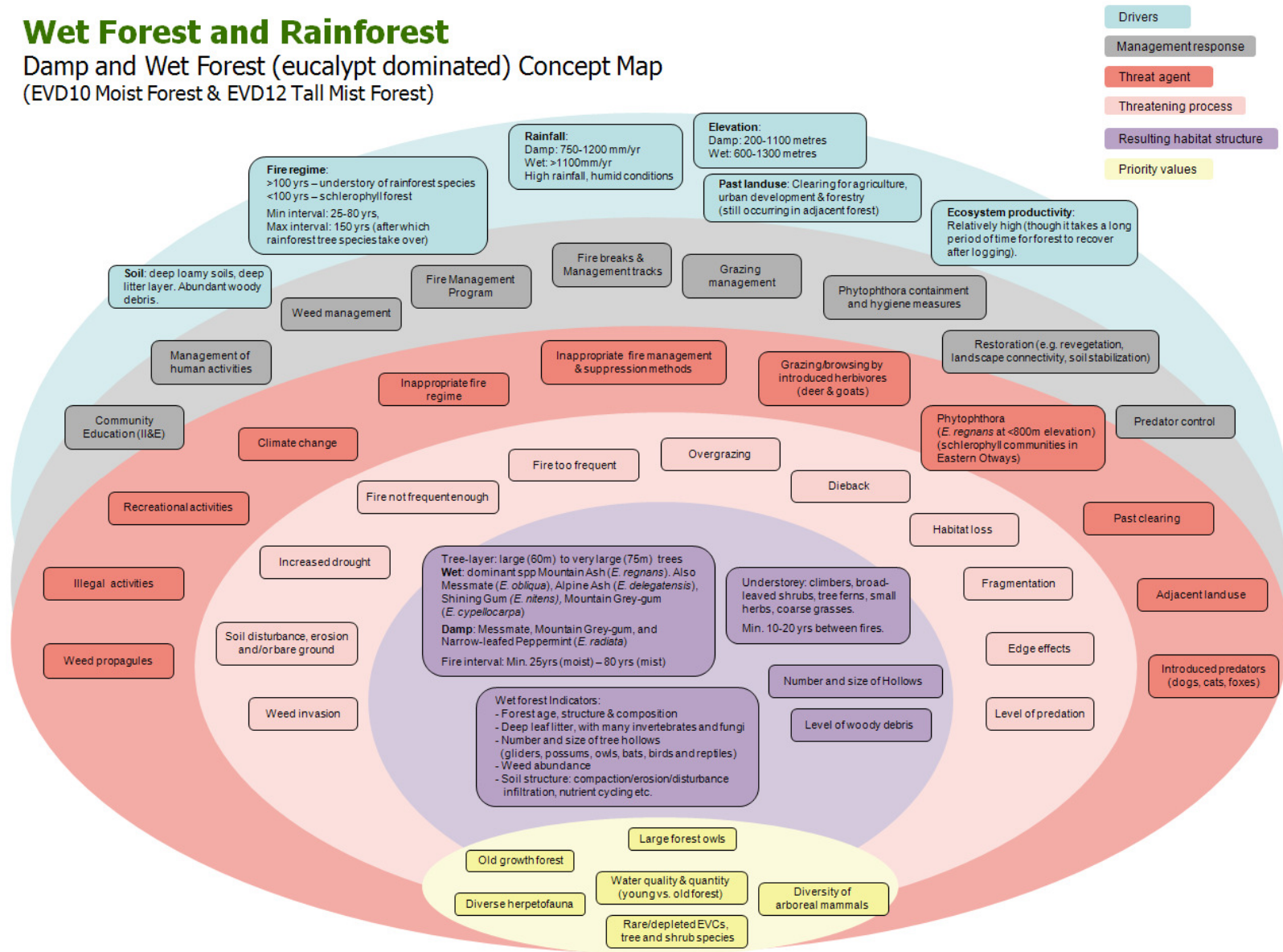
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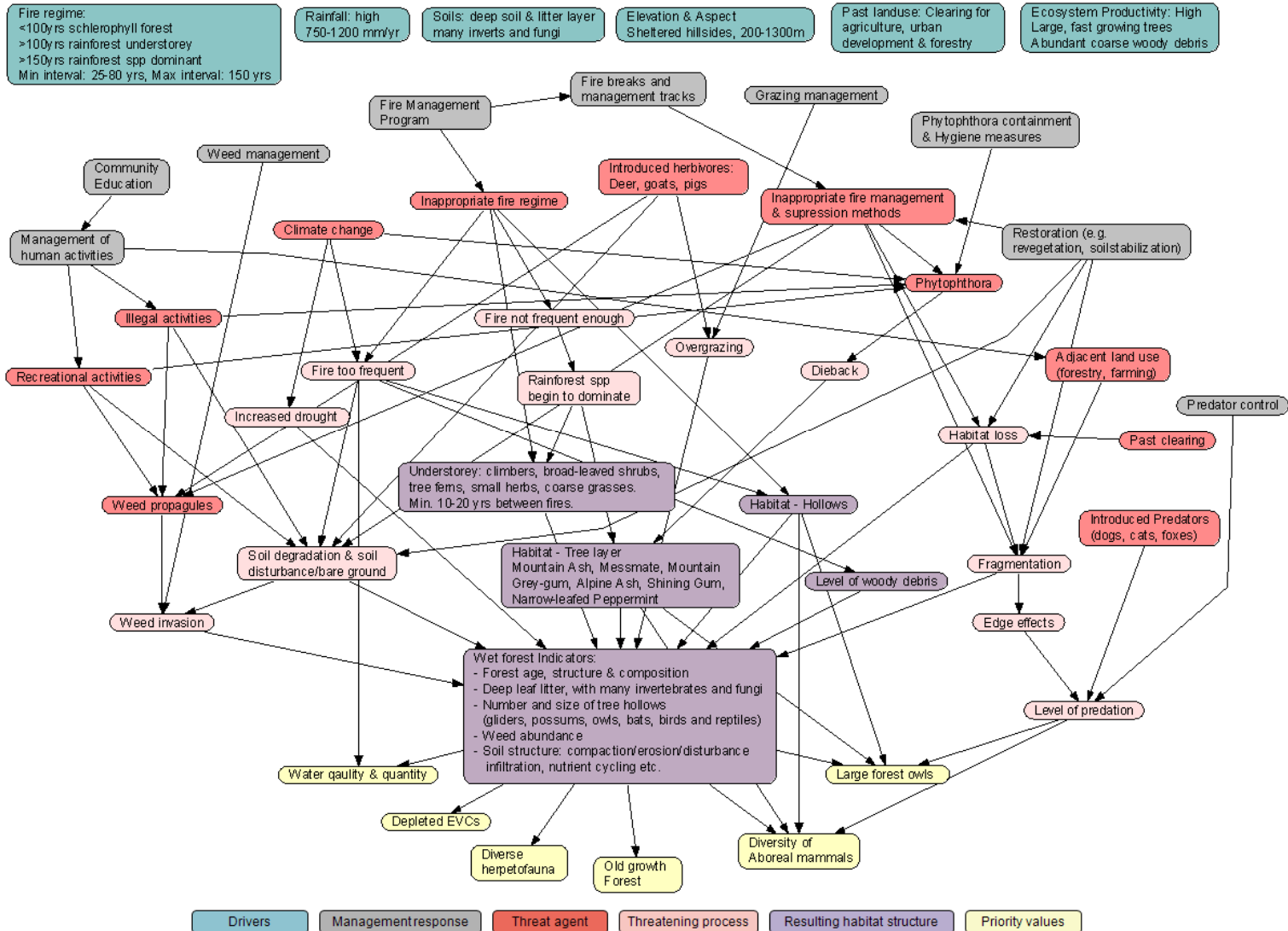
Wet Forest and Rainforest

Damp and Wet Forest (eucalypt dominated) Concept Map (EVD10 Moist Forest & EVD12 Tall Mist Forest)

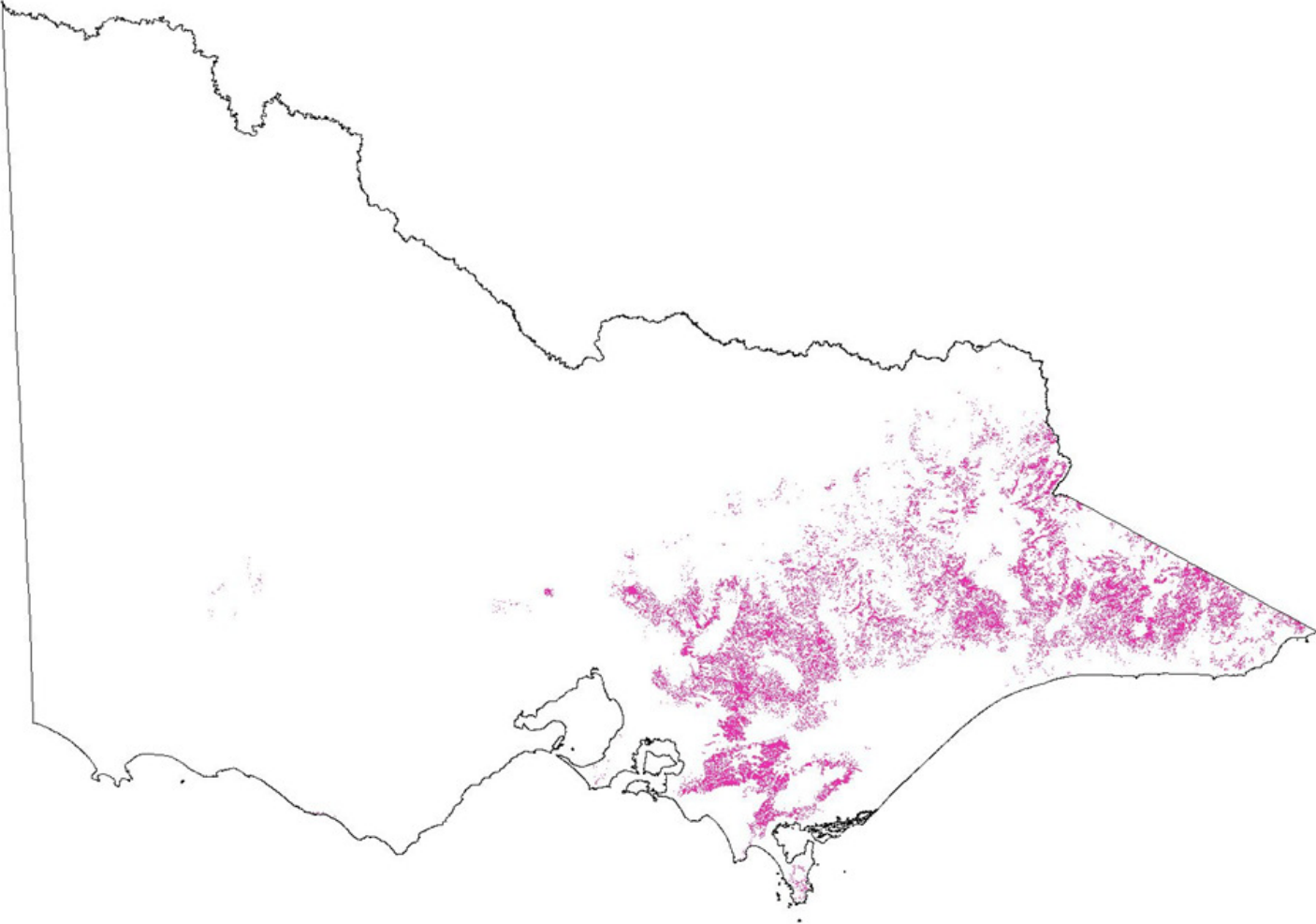


Wet Forest and Rainforest

Wet and Damp Forest Causal Model (EVD10 Moist Forest & EVD12 Tall Mist Forest)



EVD 10 Moist Forest

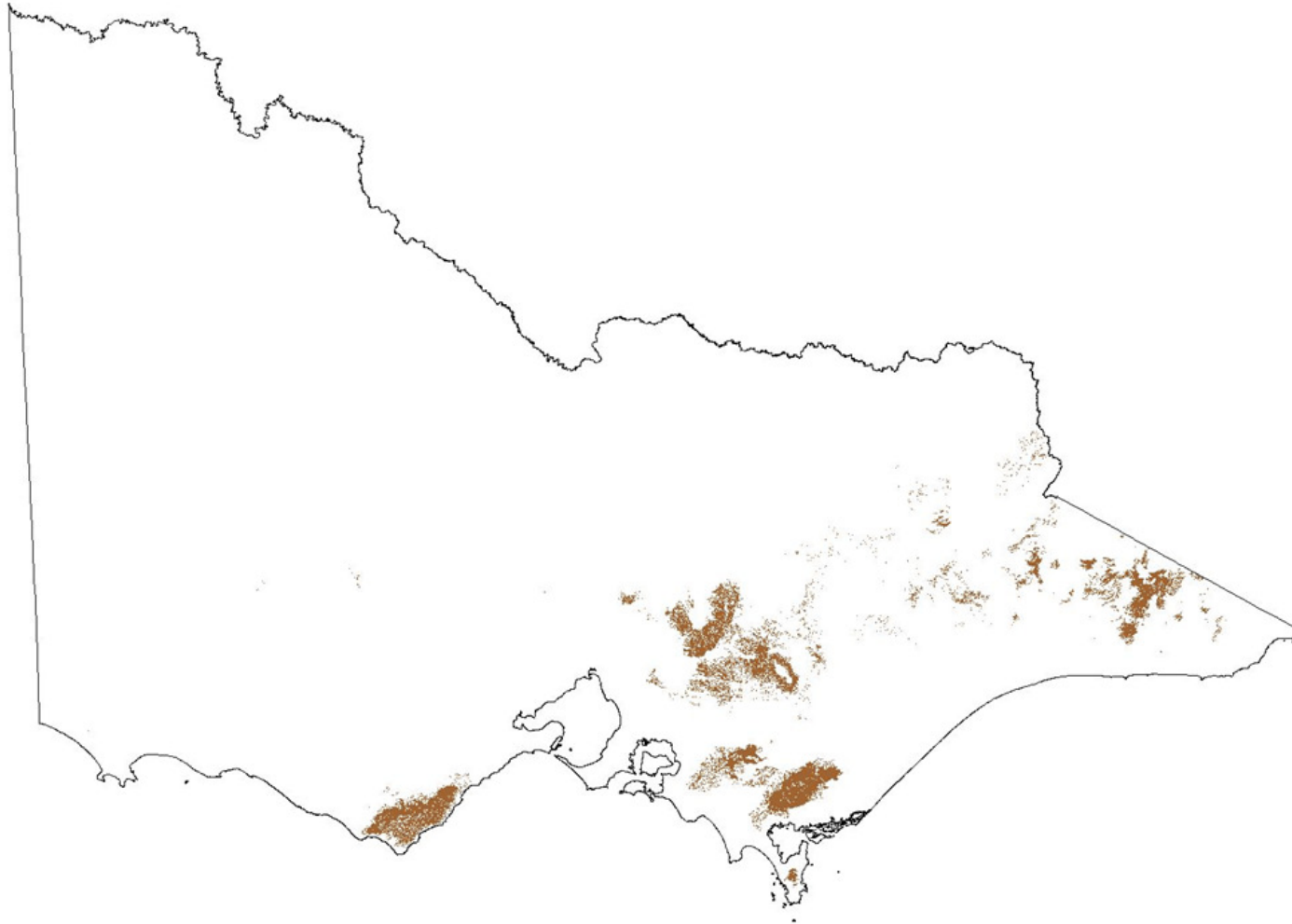


100 0 100 200 Kilometers



A58

EVD 12 Tall Mist Forest



100 0 100 200 Kilometers



A59

6.6. Wet Forest & Rainforest – Rainforest (EVD11 Closed Forest)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.6.1. Drivers

Fire regime: Rainforest flora is generally fire sensitive and shade tolerant. This ecosystem type only burns in exceptional circumstances (e.g. after protracted drought). The minimum fire interval is 80 years, there is no upper limit (Cheal 2010).

Soil: Deep loamy soil and large amounts of litter and woody debris.

Rainfall: Rainfall in this ecosystem type is high. Cool temperate rainforest occurs at higher altitudes (700-1200m) with higher rainfall (average 700-1100 mm per year); warm temperate rainforest occurs at lower altitudes (200-1000m) with lower rainfall (average 700-1100 mm per year). Rainforest is generally associated with creeks, rivers and other drainage lines, commonly on sheltered south facing gullies.

Past landuse: Selective timber extraction, now discontinued.

Ecosystem productivity: Relatively high.

6.6.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Weeds in this ecosystem type include introduced climbers, brambles (e.g. Giant Bramble *Rubus alceifolius*), thistles, broad-leafed shrubs and grasses.

Recreational activities: These include hiking and camping.

Illegal activities: These include the theft of flora and fauna (e.g. tree ferns), rubbish dumping and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: The most important impact of climate change on these systems is likely to be increased drought (drought more frequent and hotter) leading to increased frequency of fire. In the past, this ecosystem type has burnt only in exceptional circumstances (e.g. following a prolonged drought). It is protected from fire by topographical position and high moisture levels, typically occurring in moist gullies. However, increased temperatures and decreased runoff may result in an increase in fire frequency in this ecosystem type.

Inappropriate fire regime: If fire is too frequent in this ecosystem type (i.e. an interval of less than 80 years) the species which occur in surrounding eucalypt forest will begin to dominate and will eventually take over. There is no upper limit for fire interval, as rainforest species do not require fire for regeneration.

Inappropriate fire management & suppression methods: These can include the creation of fire breaks/access tracks in vegetation types that are sensitive to disturbance (where natural recovery is unlikely and/or restoration is difficult), or in areas that may already be highly fragmented, or rare and restricted (which is the case for rainforest). It may also include the use of fire retardants and wetting agents and foams. The impacts of fire breaks and access tracks include habitat loss and fragmentation (increasing edge effects), soil erosion (increased turbidity and sedimentation of waterways), soil compaction (from the use of heavy machinery) and weed invasion.

Introduced herbivores: Include deer and pigs.

Myrtle wilt: Myrtle Wilts affects the tree species *Nothofagus cunninghamii* and is caused by infection with the native fungus *Chalara australis*. The fungus invades either via wounds on the outer bark or root contact with infected plants, and may be exacerbated by damage caused during management activities (e.g. road and track construction and maintenance). The fungi spreads by air and water-borne spores, and infection makes trees more prone to attack by borers. The incidence of Myrtle Wilt decreases with elevation, probably because the decreasing temperatures inhibit fungal activity (DSE 2005), rising temperatures with climate change may reduce this effect. Myrtle Wilt is a serious problem in parts of the Great Otway National Park and in the central highlands.

Past clearing: Selective timber extraction

Adjacent landuse: Surrounding forest may have been removed or altered, increasing the potential for edge effects (see below). Protection of rainforest from adjacent land uses will require a buffer, which should be located at least beyond the ecotone between rainforest and the surrounding sclerophyll forest (Burgman and Ferguson 1995). Disturbance within this zone should be avoided.

Introduced predators: Includes foxes, cats and wild dogs.

6.6.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Soil erosion/degradation/bare ground: Past land use and the introduction of herbivores (managed and feral) have modified vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. High rainfall and steep slopes make this ecosystem type a high erosion risk. Road and

infrastructure construction, vegetation removal and recreational activities can increase bare ground the potential for soil erosion. Car parks and picnic areas are potential sites for soil compaction and runoff; roads and tracks are a potential source of sediment which degrades water quality. Bare ground also provides the opportunity for the invasion and establishment of weed plant species.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought are a decrease in flowering and nectar flow; a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire severity and frequency.

Fire too frequent (interval too short): Intervals less than 80 years may result in loss of rainforest species (the inter-fire interval not adequate to allow species to reach reproductive maturity and produce seed, loss of these species in the seed bank). This will result in changes to vegetation composition and structure and habitat loss for dependent fauna.

Overgrazing: Goats and deer are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground).

Dieback: Dieback is the premature and rapid decline and death of trees, in this ecosystem type the most common cause of dieback is Myrtle Wilt (see above), which effects one of the main rainforest tree species, *Nothofagus cunninghamii*.

Habitat loss: This ecosystem type has a naturally small and restricted distribution in Victoria, therefore loss and/or modification of rainforest habitat has conservation implications.

Fragmentation: Rainforest in Victoria has a naturally fragmented distribution, and often occurs in isolated patches; these may be fragmented further (within habitat patches) by walking and management tracks. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance. Edge effects may occur in response to roads and walking tracks, tourist facilities, and land clearance on adjacent land, and they are particularly important in this ecosystem type as rainforest patches tend to be small and linear. A potentially important edge effect is the increase in incidence of falling branches and wind-throw, a potential factor in the spread of

Myrtle Wilt (because of the increase in wounding). Another important issue for rainforests is the change in microclimate near the forest edge, where a changes in the flux of wind, radiation and water may decrease humidity and soil moisture.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.6.4. Management Responses

Community Education (II&E): Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals. The focus of fire management in this ecosystem type is on fire suppression.

Grazing management: Grazing management in this ecosystem type would target introduced herbivores (mainly deer). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Restoration: Different restoration methods applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to

lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Specific actions may be taken to stabilize soil in actively eroding areas.

Myrtle Wilt Management: Management of Myrtle Wilt may include minimisation of wounding, breaking of root grafts (connections) between infected and uninfected trees, and/or active management of regeneration in infected stands (DSE 2005).

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.6.5. Resultant Habitat Structure

Tree species: Warm Temperate Rainforest: Blackwood (*Acacia melanoxylon*), Lillypilly (*Syzygium smithii*) and Sweet pittosporum (*Pittosporum undulatum*). Cool Temperate Rainforest: Myrtle Beech (*Nothofagus cunninghamii*), Sassafras (*Atherosperma moschatum*) and Black Olive-berry (*Elaeocarpus holopetalus*).

Understorey: Climbers, ferns, shrubs and bryophytes

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire). The level of coarse woody debris in this ecosystem type is naturally very high, as the systems have relatively high productivity.

6.6.6. References

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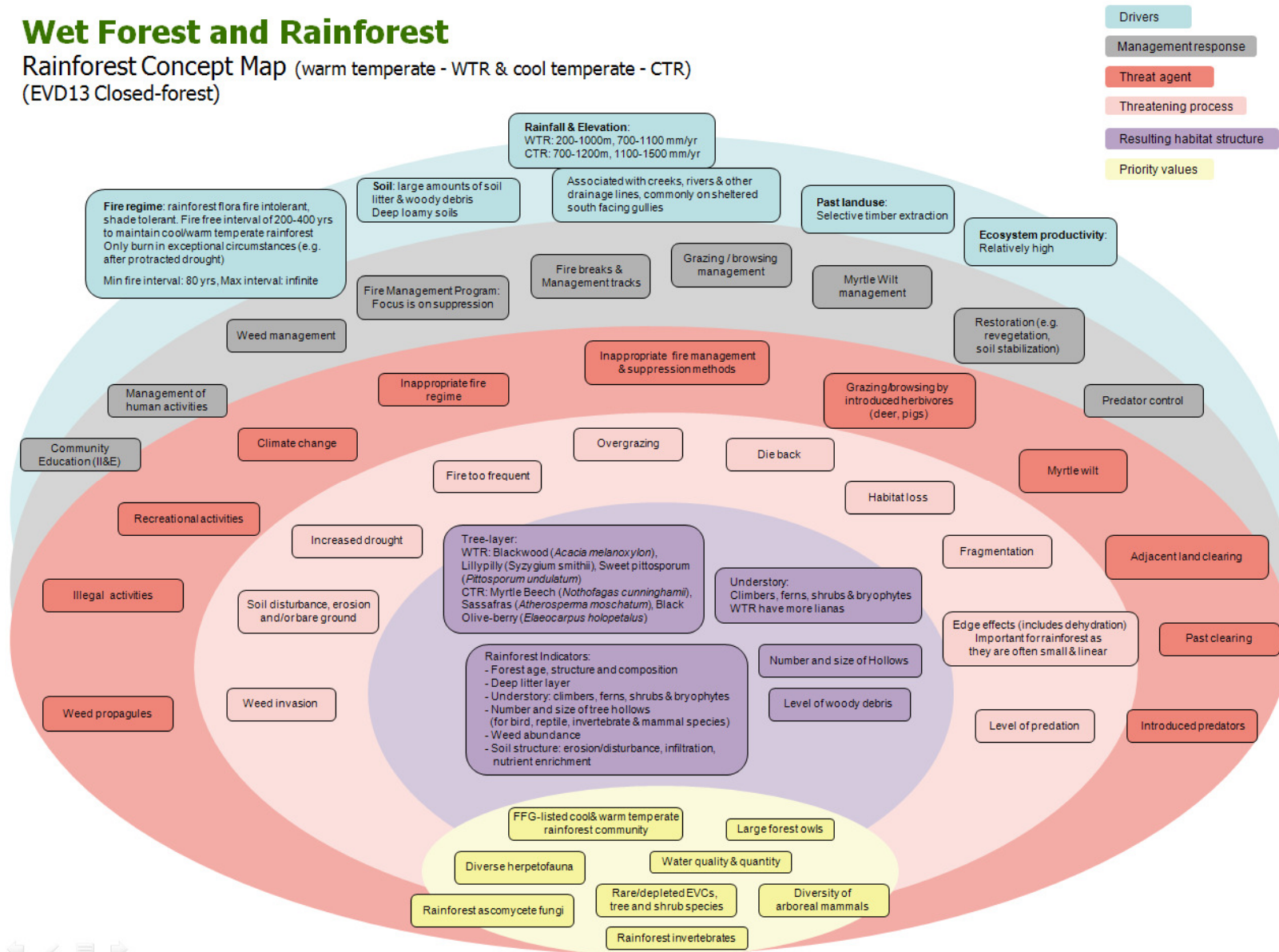
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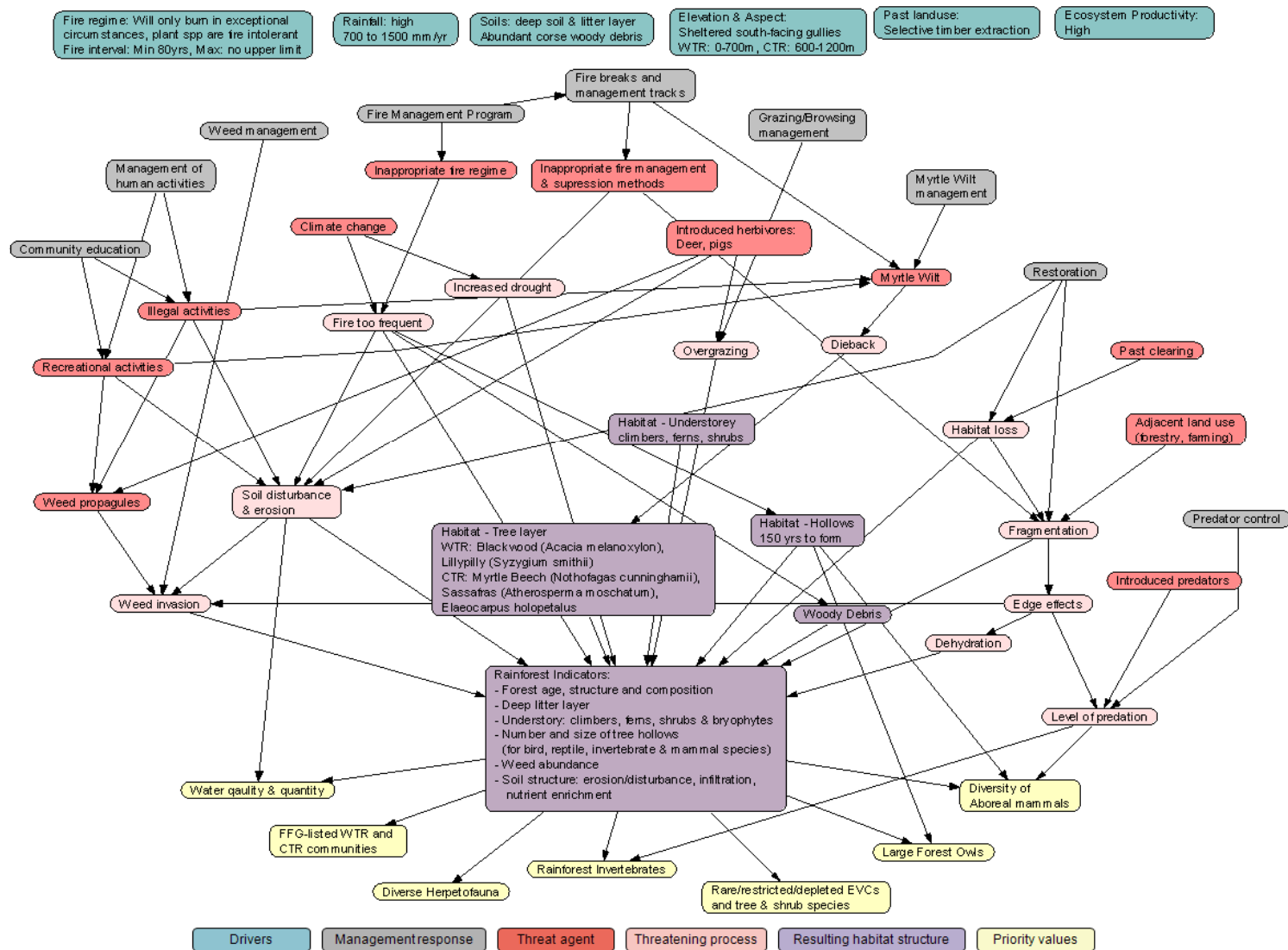
Wet Forest and Rainforest

Rainforest Concept Map (warm temperate - WTR & cool temperate - CTR)
(EVD13 Closed-forest)

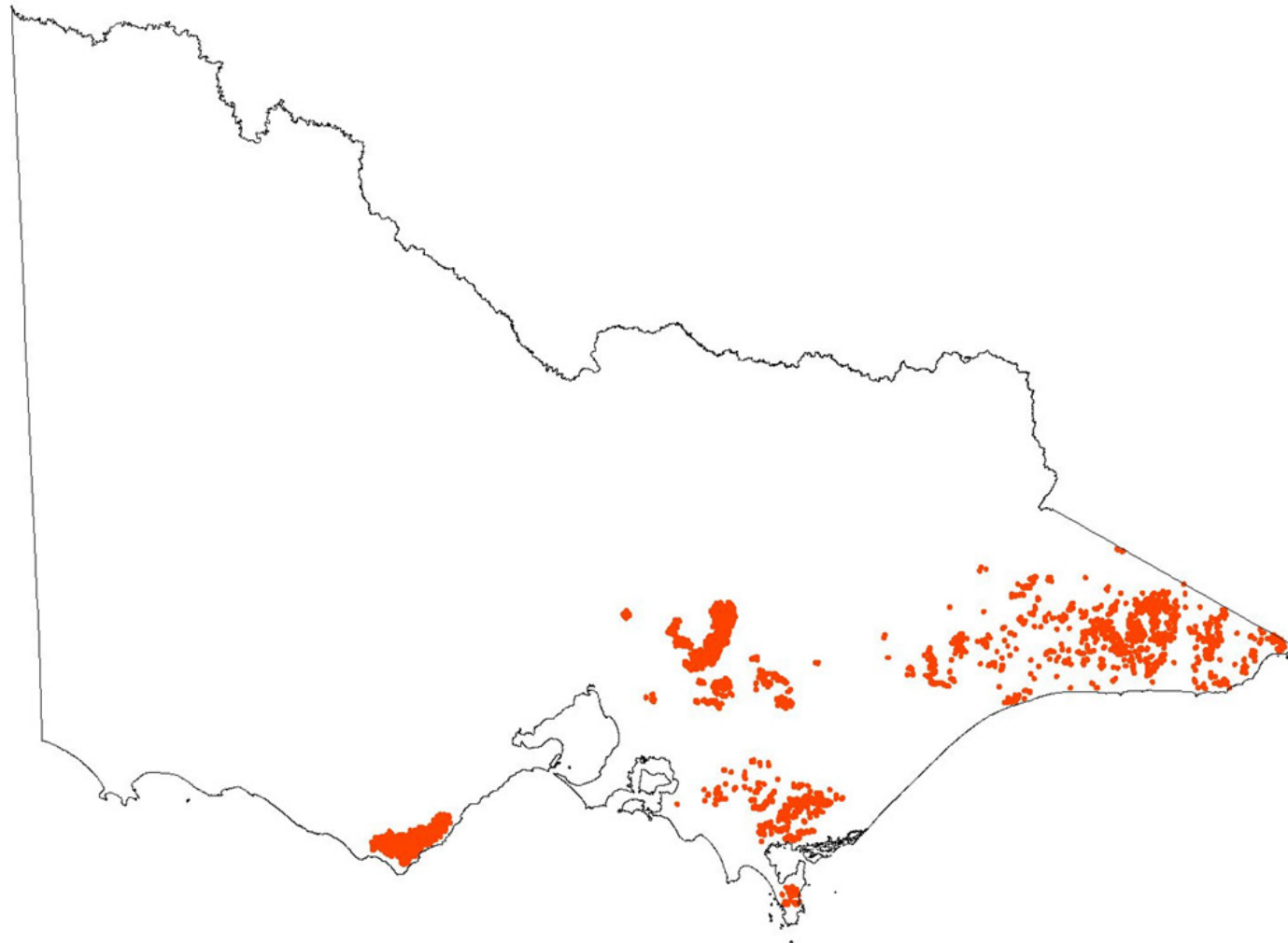


Wet Forest and Rainforest

Rainforest Casual Model (warm temperate - WTR & cool temperate - CTR)



EVD 13 Closed Forest



A69

6.7. Grassland – Themeda dominated (EVD20 Basalt Grassland)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.7.1. Drivers

Fire regime: The minimum fire interval for low severity fires is 2 years, and for high severity fires is 3 years; the maximum fire interval is 7 years (Cheal 2010). In the absence of disturbance Themeda tussocks come to dominate, closing inter-tussock gaps. Periodic removal of biomass (typically by fire) is necessary to maintain structural diversity and flora and fauna species richness.

Soil: Basalt derived and fertile, generally heavy clays that may become waterlogged in winter but dry and crack over summer.

Rainfall: Moderate, average between 550-800 mm per year.

Past landuse: This ecosystem type has been extensively cleared and/or substantially modified, mostly for cropping and grazing, also for urban development; is poorly represented by the reserve system.

Ecosystem productivity: Relatively high (compared to non-Themeda dominated grasslands).

6.7.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include African Box-thorn, Artichoke Thistle, Horehound, Paterson's Curse, Common Prickly pear, Common Bindweed, Variegated Thistle and Serrated Tussock. Environmental weeds include Canary-grass, Bridal Creeper and Chilean needle grass.

Recreational activities: Due to the small size of many grassland parks and reserves, recreational activities are generally limited to passive activities such as walking, picnicking, sight-seeing and nature study.

Illegal activities: These include the theft of flora and fauna (e.g. orchids and herbs), rubbish dumping and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: the most important impact of climate change on these systems is likely to be increased drought, which will decrease flowering and seed production, and decrease in plant and animal recruitment.

Inappropriate fire regime: Fire interval may be too short (intervals less than 2 years for low severity fire and less than 3 years for high severity fire), or too long (7 years or more), some flora and fauna species are sensitive to the time of year that fire occurs.

Inappropriate grazing regime (sheep & cattle): In the absence of disturbance Themeda tussocks come to dominate, closing inter-tussock gaps. Periodic removal of biomass is necessary and this is usually achieved by the use of fire. However, in areas where this may not be possible (e.g. when grassland is adjacent to roads and other infrastructure) grazing may be used as the disturbance agent. Careful monitoring of the response of flora and fauna to grazing is necessary to ensure the grazing regime is appropriate, i.e. that it is meeting management and conservation objectives. Impacts on soil should also be carefully monitored.

Introduced herbivores: Rabbits are the most common introduced herbivore in this ecosystem type, and may inhibit vegetation regeneration.

Past clearing & land use: This ecosystem type was extensively cleared for cropping, grazing and urban development, and is highly fragmented. Past land uses included grazing of sheep and cattle, the introduction of pasture plants (common species include Rye Grass *Lolium perenne* and Clover *Trifolium subterraneum*) and fertilizer use. Many undesirable effects associated with past use persist, such as weed invasion and changes to the structure and composition of native vegetation communities.

Adjacent landuse: Parks and reserves are surrounded by many different land uses and these can have impacts on the ecosystems within parks. Agriculture and urban development in surrounding areas are a potential source of weed propagules, and runoff containing nutrients, pesticides and herbicides. Urban stormwater runoff may also contain sewage effluent and pollutants (e.g. heavy metals). The modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Introduced predators: Includes foxes and cats.

6.7.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place. In grasslands, the past use of fertilizers has encouraged the growth of annual exotics, which were introduced to native grasslands as pasture plants. As the abundance of native plant species is reduced the soil seed bank also becomes diminished. This can occur rapidly as the seeds of most native grassland species are short-lived. Through this process the seed bank may become dominated by exotic annuals.

Soil degradation/disturbance/bare ground: Soil stability in this ecosystem type is reduced by heavy grazing pressure (McIntyre and Tongway 2005). Past land use and the introduction

of herbivores (managed and feral) have modified vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Bare ground provides the opportunity for the invasion and establishment of weed plant species. Grassland soils are vulnerable to physical disturbance (from vehicles and foot traffic) when they are dry and also when they are waterlogged. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Increased drought: Increased drought is likely to impact on flowering and seed production in this ecosystem type, and the rate of successful recruitment, leading to changes in vegetation composition and structure, an overall decrease in vegetation cover and habitat loss for dependent fauna.

Season of fire: Burning can be timed to maximize the negative effect on weed species and maximize the positive effects on native flora and fauna (Prober et al. 2004). Conversely, fire at other times may have a negative impact on native plant and animal species (e.g. fire planning in grasslands where Striped Legless Lizards occur should take into account their requirement for fire refuges – cracks in the ground which form in dry conditions at the end of summer).

Fires not frequent enough (interval too long): It is estimated by Morgan and Lunt (1999) that intervals of less than five years are necessary to maintain the health of Themeda-dominated systems. If the inter-fire interval exceeds six years the number of shoots that sprout from the base of the tussock (tillers), and the total number of tussocks, begin to decline. Morgan and Lunt (1999) found that if the inter-fire interval reached 11 years few live tillers or tussocks remained and that below-ground biomass had been reduced. They also found that with increasing time since fire the canopy of live leaves would become elevated above the soil surface, dead leaves accumulated around and over the tussock base and productivity declined. With no disturbance for 11 years the canopy of the sward began to collapse and form a thick layer of dead material over the soil surface. Morgan and Lunt (1999) noted that a single fire 12 years after last burn did not immediately return the grassland to a good state.

Burning is also important for inter-tussock native flora that can be rapidly eliminated from grasslands due to severe competition from Themeda in the absence of disturbance. The decline in floral diversity may be irreversible given that the seed bank for many of these species is transient. These species are unlikely to return without management intervention (Prober and Thiele 2005). Faunal species, such as the Earless Dragon and Plains Wanderer, also rely on the creation of inter-tussock spaces. Burning in patches is important as it

minimizes the potential for soil erosion, and also provides areas to act as refuge for faunal species (Prober and Thiele 2005).

Overgrazing: Overgrazing can affect soil and water function and ultimately cause erosion. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground). McIntyre and Tongway (2005) found that water infiltration and nutrient cycling indices declined as grazing pressure increased. They also found that the stability index for soils (estimated using amount of bare ground, litter cover, vegetation cover, erosion, surface resistance to disturbance, etc) was reduced in the most heavily grazed plots.

Elevated soil nutrients: Soil nutrients (mainly phosphate and nitrogen) may be elevated in grasslands, from past use of fertilizers, breakdown of cattle and sheep manure, and/or from nutrient laden runoff.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of habitat, which has affected the distribution and abundance of many plant and animal species. Existing (remnant) habitat may also be under pressure from degrading processes which can contribute to further habitat loss. This ecosystem type has been extensively cleared and/or substantially modified, mostly for cropping and grazing, also for urban development.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.7.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals. In the absence of disturbance Themeda tussocks come to dominate, closing inter-tussock gaps. Periodic removal of biomass, usually by fire, is necessary to maintain structural diversity and flora and fauna species richness.

Fire breaks and management tracks: These contribute to the effects of fragmentation, and may lead to soil disturbance (erosion and bare ground), soil compaction and weed invasion.

Grazing management: Rabbits are known to inhibit the natural regeneration of vegetation and are a priority for control in most grassland reserves. The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Restoration: Different restoration methods are applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas. Restoration in this ecosystem type may include manipulations of grazing pressure (native and introduced) and fire regimes, mowing or slashing, selective use of herbicides, carbon addition, and the re-introduction of native species.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.7.5. Resultant Habitat Structure

Ground layer: The ground layer in this ecosystem type is dominated by *Themeda triandra*, and also *Austrostipa* and *Austrodanthonia* spp. A diversity of forbs, herbs, sedges and lilies occur in the inter-tussock spaces. There may be a few emergent trees (see below) and shrubs are largely absent.

Tree species: Occasional trees occur in this ecosystem type, most common is River Red Gum (*E. camaldulensis*), sometimes also Yellow Box (*E. melliodora*) , Yellow Gum (*E. leucoxylon*) and Grey Gum (*E. microcarpa*)

6.7.6. References

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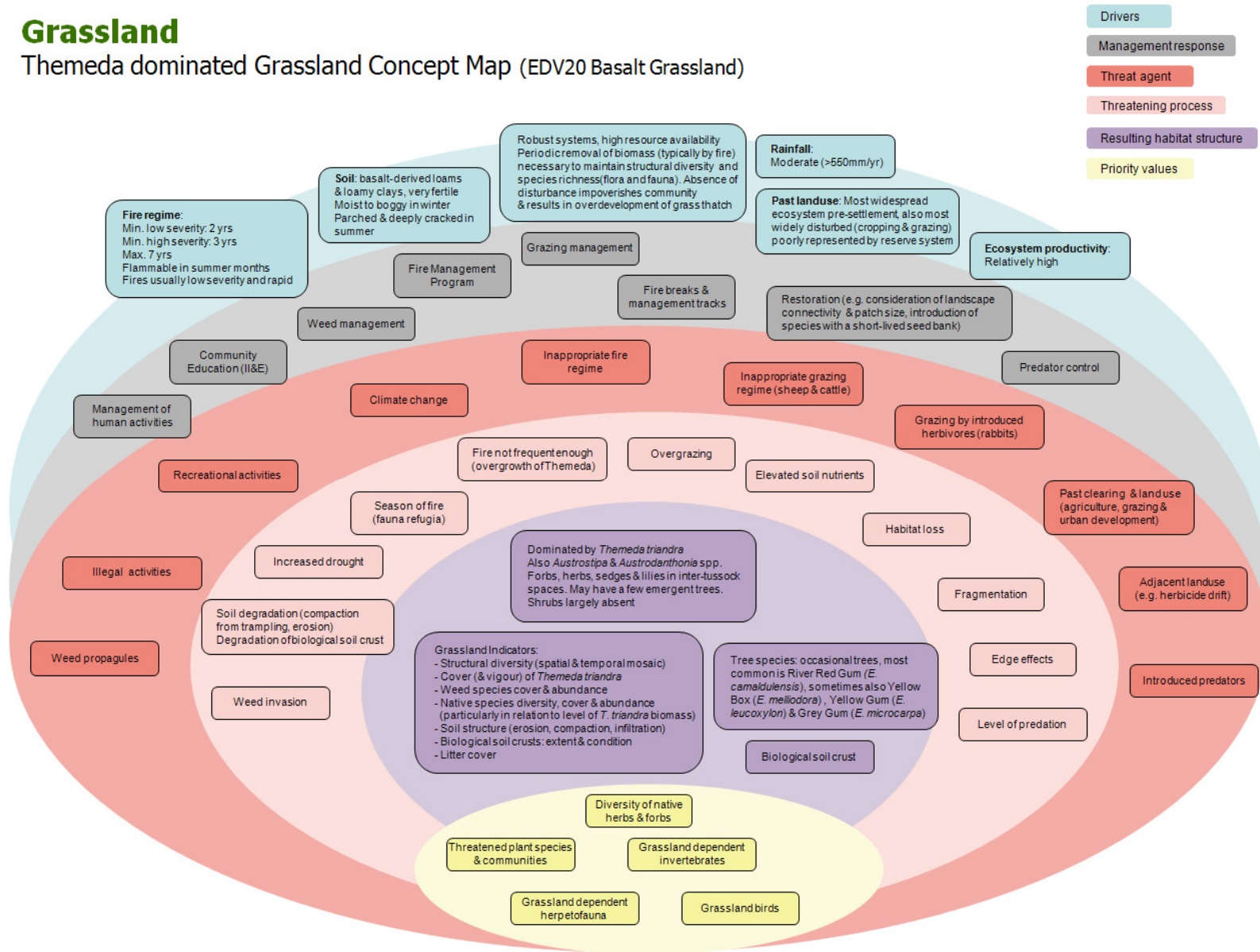
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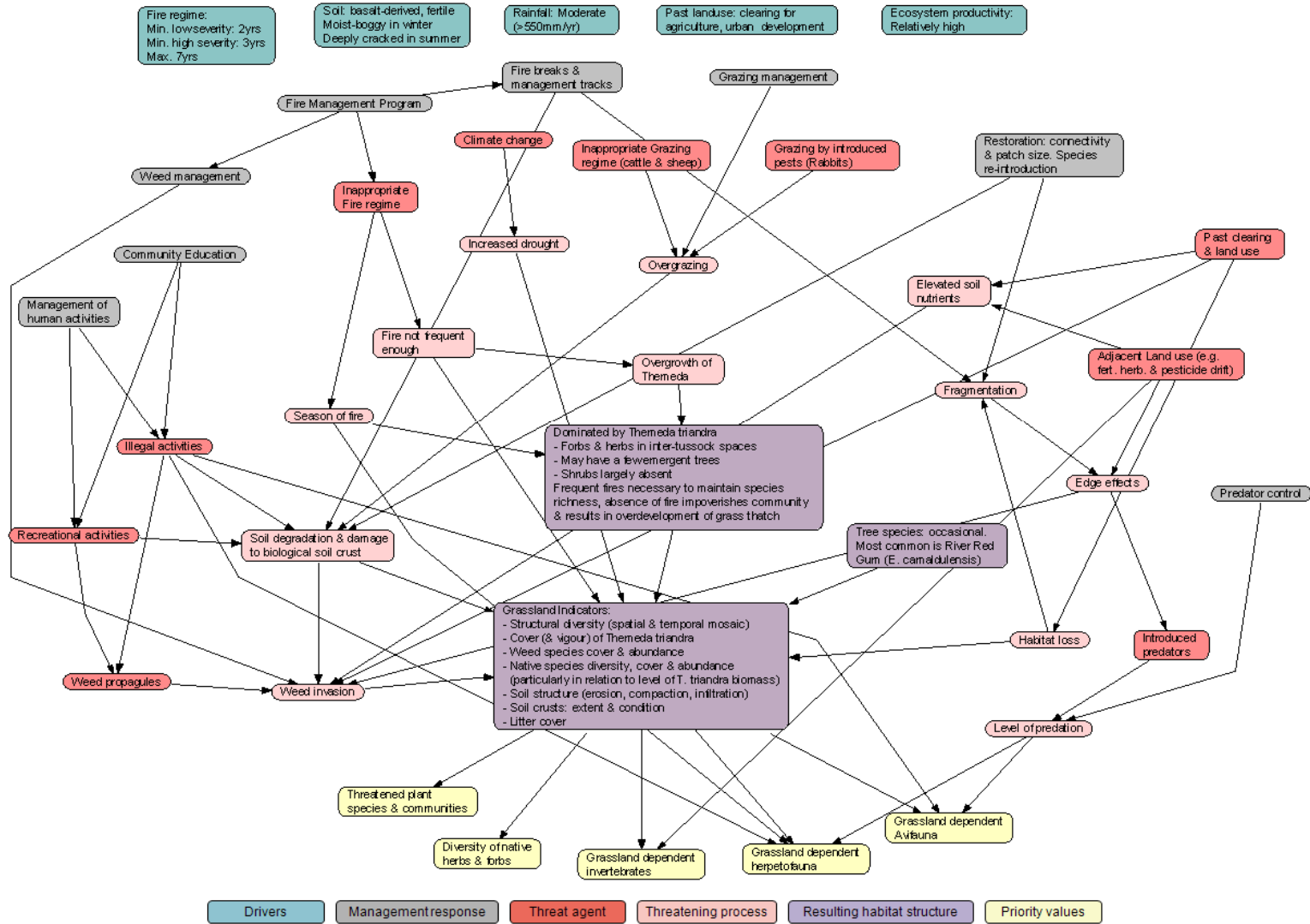
Grassland

Themeda dominated Grassland Concept Map (EDV20 Basalt Grassland)

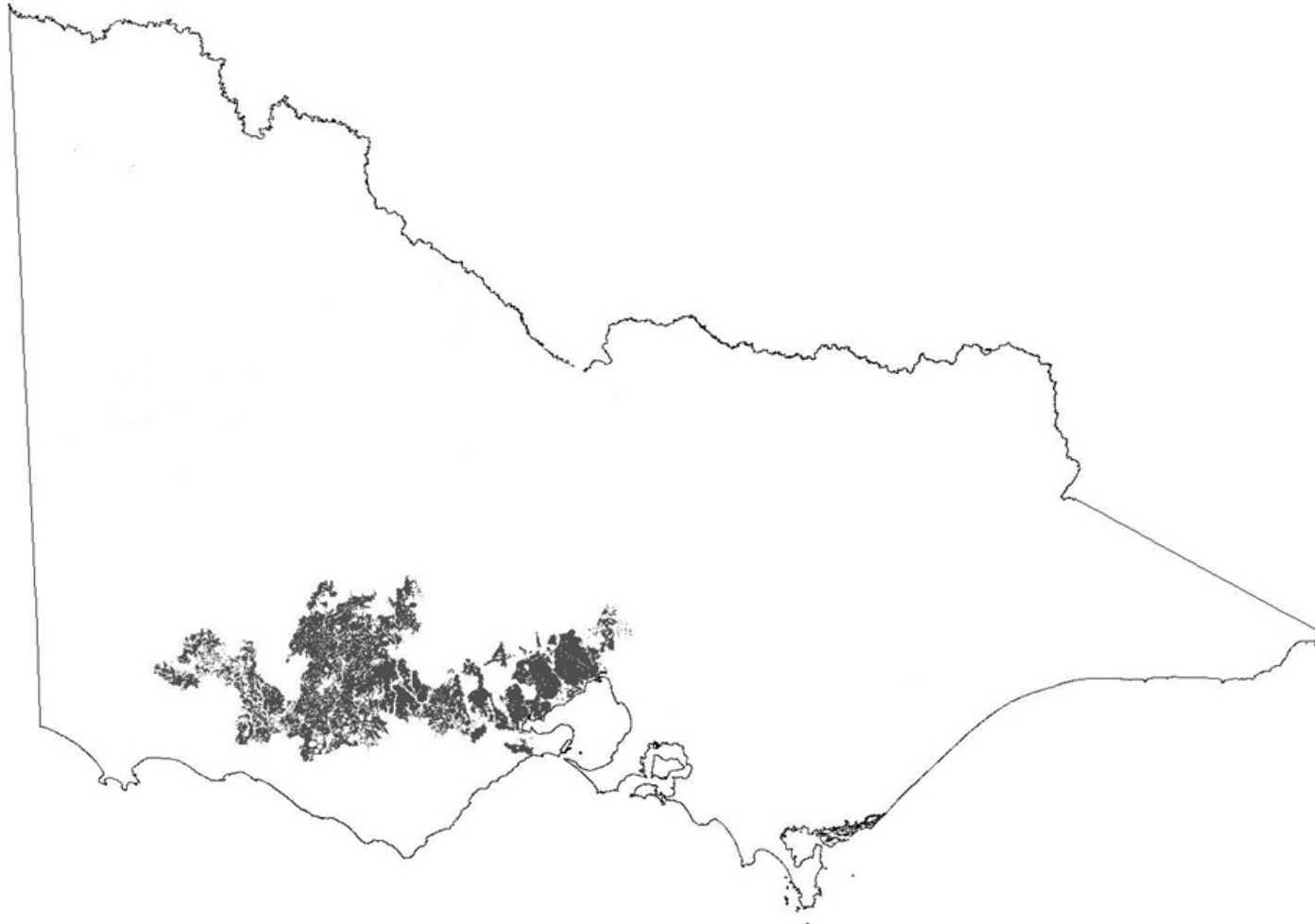


Grassland

Themeda dominated Grassland Causal Model (EDV20 Basalt Grassland)



EVD 20 Basalt Grassland



100 0 100 200 Kilometers



A80

6.8. Grassland – Non-Themeda dominated (EVD21 Alluvial Plains Grassland)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.8.1. Drivers

Fire regime: Minimum fire interval for low severity fires is 2 years, and for high severity fires is 3 years; the maximum fire interval is 30 years (Cheal 2010).

Soil: Fertile alluvial loamy clays. Moist in winter, parched and deeply cracked in summer.

Rainfall: Moderate to low, average less than about 550 mm per year.

Past landuse: This ecosystem type has been extensively cleared and/or substantially modified, mostly for cropping and grazing (mostly sheep), also for urban development.

Ecosystem productivity: Relatively low (compared to Themeda dominated grasslands).

6.8.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include African Box-thorn, Bathurst Burr, Horehound, Wheel Cactus, Paterson's Curse and Bridal Creeper. These species tend to invade disturbed areas (recently cropped land, rabbit warren areas, along internal vehicle tracks and in stock camps under isolated stands of trees). Annual Rye-grass and Wild Oats are widespread in some parks. At Terrick Terrick National Park weed invasion threatens the integrity of the park's vegetation communities and the survival of small isolated populations of flora species, including populations of the threatened Hairy Tails and Rohrlach's Bluebush (Parks Victoria 2004).

Recreational activities: These include camping, bush walking, picnicking, sight-seeing and nature study.

Illegal activities: These include the theft of flora and fauna (e.g. orchids and herbs), rubbish dumping and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: the most important impact of climate change on these systems is likely to be increased drought, which is likely to change species abundance and community composition.

Inappropriate fire regime: Fire interval may be too short (intervals less than 2 years for low severity fire and less than 3 years for high severity fire), or too long (30 years or more), some vegetation components and fauna species are sensitive to the time of year that fire occurs. Burning in patches is important as it minimizes the potential for soil erosion, and also provides areas to act as refuge for fauna species (Prober and Thiele 2005).

Inappropriate grazing regime (sheep): Some parks (e.g. Terrick Terrick National Park) use sheep grazing to maintain conservation values (primarily flora diversity). Careful monitoring

of the response of flora and fauna to grazing is necessary to ensure the grazing regime is appropriate, i.e. that it is meeting management and conservation objectives. Impacts on soil should also be carefully monitored.

Introduced herbivores: Rabbits are the most common introduced herbivore in this ecosystem type, and are known to inhibit vegetation regeneration.

Past clearing & land use: This ecosystem type was extensively cleared for cropping, grazing and urban development, and is highly fragmented. Past land uses included grazing of sheep and cattle, the introduction of pasture plants (common species include Rye Grass *Lolium perenne* and Clover *Trifolium subterraneum*) and fertilizer use. Many undesirable effects associated with past use persist, such as weed invasion and changes to the structure and composition of native vegetation communities.

Adjacent landuse: Parks and reserves are surrounded by many different land uses and these can have impacts on the ecosystems within parks. Agriculture and urban development in surrounding areas are a potential source of weed propagules, and runoff containing nutrients, pesticides and herbicides. Urban stormwater runoff may also contain sewage and pollutants (e.g. heavy metals). The modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Introduced predators: Includes foxes and cats.

6.8.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place. In grasslands, the past use of fertilizers has encouraged the growth of annual exotics, which were introduced to native grasslands as pasture plants. As the abundance of native plant species is reduced the soil seed bank also becomes diminished. This can occur rapidly as the seeds of most native grassland species are short-lived. In addition, grazing has the effect of producing bare ground, which also encourages weed invasion.

Soil degradation/disturbance/bare ground, damage to biological soil crust: Grassland soils are vulnerable to physical disturbance (from vehicles or even foot traffic) when they are dry (at the end of summer) and also when they are waterlogged. Land clearing and the introduction of herbivores (managed and feral) have reduced the cover of vegetation and biological soil crusts in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth.

Bare ground provides the opportunity for the invasion and establishment of weed species. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Increased drought: Increased drought is likely to impact on the frequency reproductive events and the rate of successful recruitment in this ecosystem type. This is likely to lead to changes in vegetation composition and structure, and an overall decrease in vegetation cover. Biological soil crusts may also be affected by drought due to a decrease in the number of days that are suitable for growth, which is likely to make them more vulnerable to disturbance (slower to recover).

Season of fire: Burning can be timed to maximize the negative effect on weed species and maximize the positive effects on native flora and fauna (Prober et al. 2004). Conversely, fire at other times may have a negative impact on native plant and animal species (e.g. fire planning in grasslands where Striped Legless Lizards occur should take into account their requirement for fire refuges – cracks in the ground which form in dry conditions at the end of summer).

Fires not frequent enough (interval too long): If the fire interval in this ecosystem type is greater than 30 years species vegetation composition and structure is likely to change, with an increasingly common chenopod shrub layer (e.g. *Atriplex leptocarpa*, *Enchylaena tomentosa*, *Maireana decalvans*, *Maireana rohrlichii*, *Sclerolaena muricata*). Some inter-tussock native flora may have a strong response to fire, however it seems they are also able to regenerate without fire.

Fires too frequent (interval too short): The effects of a single fire event would be minimal and short-lived on existing grassland vegetation; however, fauna species that depend on grassland vegetation, (e.g. Plains wanderer, Little Button Quail and Striped Legless Lizard) may be greatly affected, especially by extensive fires over large areas of grassland vegetation (lack of refuge habitat).

Overgrazing: Overgrazing may occur in this ecosystem type because feral species (e.g. rabbits) or managed grazers (e.g. sheep). Overgrazing tends to reduce the cover and abundance of palatable species and increase the cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground).

Elevated soil nutrients: Soil nutrients (mainly phosphate and nitrogen) may be elevated in grasslands, from past use of fertilizers, breakdown of cattle and sheep manure, and/or from nutrient laden runoff.

Habitat loss: Past land clearing has resulted in the loss and fragmentation of habitat, which has affected the distribution and abundance of many plant and animal species. Existing (remnant) habitat may also be under pressure from degrading processes which can contribute to further habitat loss. This ecosystem type has been extensively cleared and/or substantially modified, mostly for cropping and grazing, also for urban development.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions. Internal fragmentation (from walking tracks and management tracks) may also be an issue (e.g. Terrick Terrick National Park Management Plan outlines that the track network may need to be rationalized to decrease fragmentation).

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.8.4. Management Processes

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Fire breaks and management tracks: These contribute to the effects of fragmentation, and may lead to soil disturbance (erosion and bare ground), soil compaction and weed invasion.

Grazing management: The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora). Rabbits are known to inhibit the natural regeneration of vegetation and are a priority for control in most grassland reserves. Some parks (e.g. Terrick Terrick National Park) use sheep grazing to maintain conservation values (primarily flora diversity). Careful monitoring of the response of flora and fauna to grazing is necessary to ensure the grazing regime is appropriate, i.e. that it is meeting management and conservation objectives. Impacts on soil should also be carefully monitored.

Restoration: Different restoration methods applied to the different ecosystem types. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas. Restoration in this ecosystem type may include manipulations of grazing pressure (managed and feral species) and fire regimes and the re-introduction of native species.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.8.5. Resultant Habitat Structure

Ground layer: The ground layer in this ecosystem type is dominated by Wallaby grass (*Austrodanthonia spp.*), Spear grass (*Austostipa spp.*), and Windmill grass (*Chloris truncate*); a diverse herb flora may be co-dominant with the grass species. Chenopod shrubs are also common and include *Atriplex spp.*, *Maireana spp.* and *Enchylaena tomentosa*. There may be a few emergent trees (see below).

Tree species: occasional trees, most common are *Acacia oswaldii*, River Red Gum (*E. camaldulensis*) and Black Box (*E. largiflorens*).

Biological soil crusts: Biological soil crusts are made up of a variety of organisms, including mosses, liverworts, cyanobacteria, algae, lichens, fungi, and bacteria. They grow in the uppermost layers of the soil.

6.8.6. References

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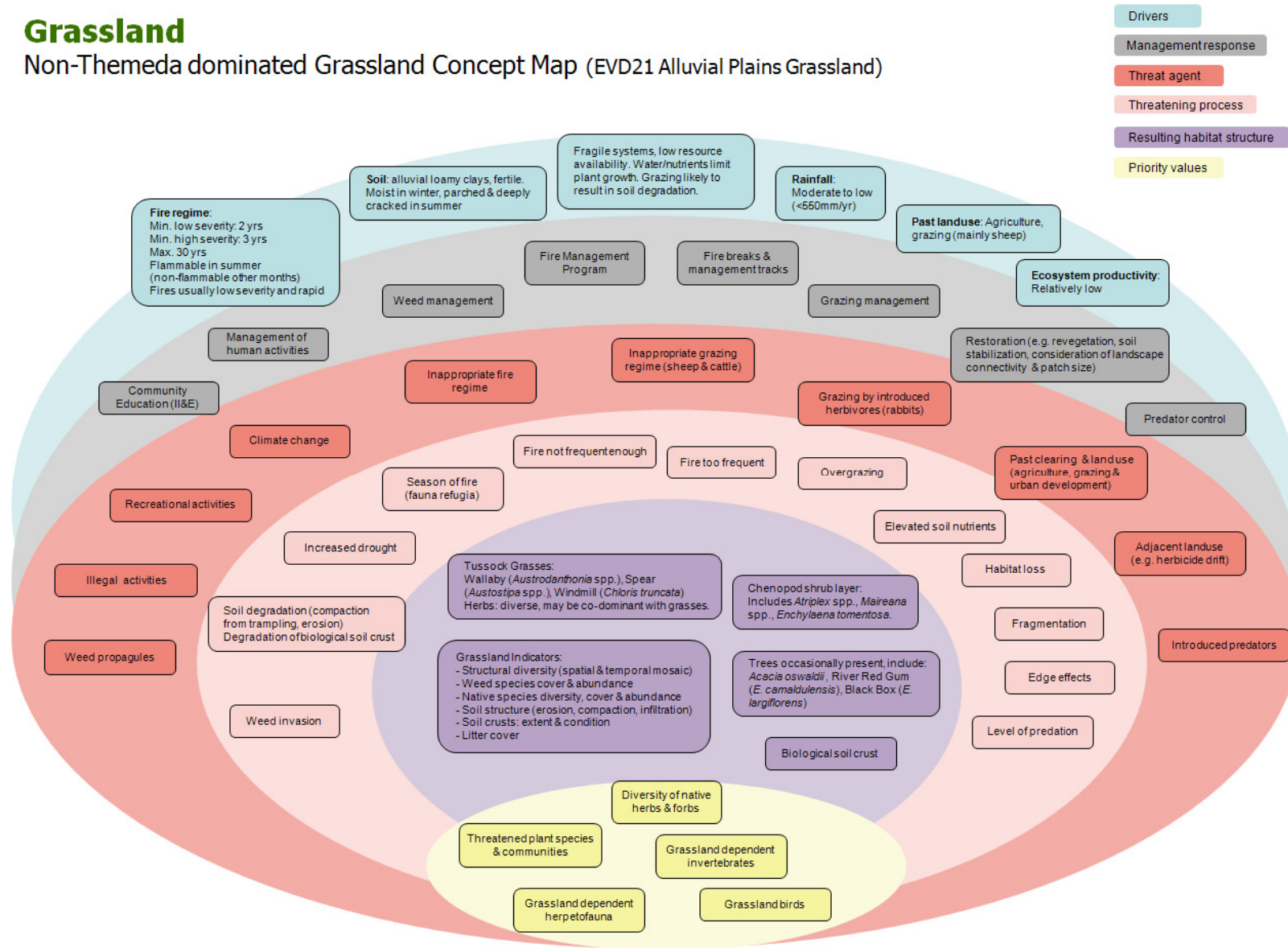
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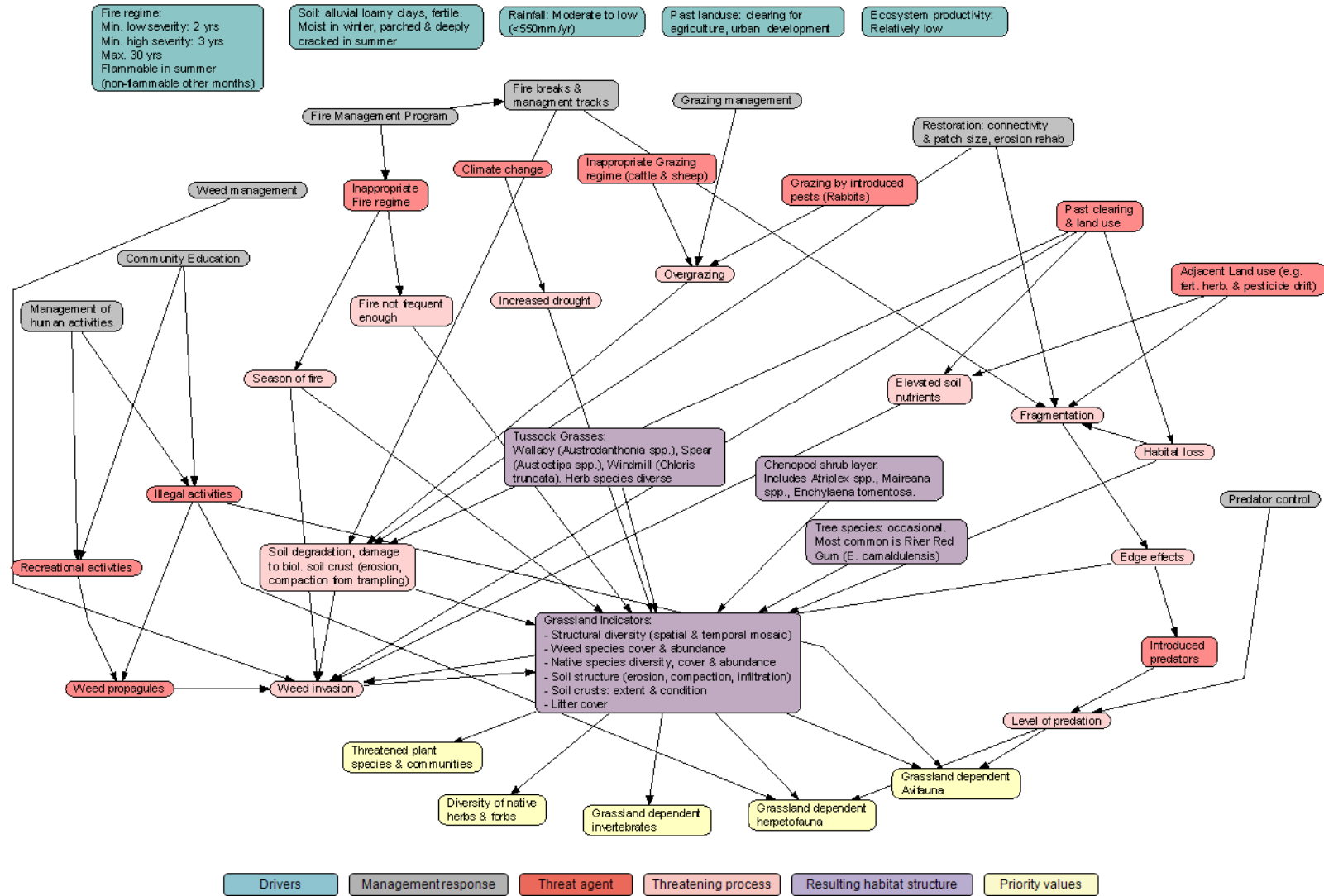
Grassland

Non-Themeda dominated Grassland Concept Map (EVD21 Alluvial Plains Grassland)

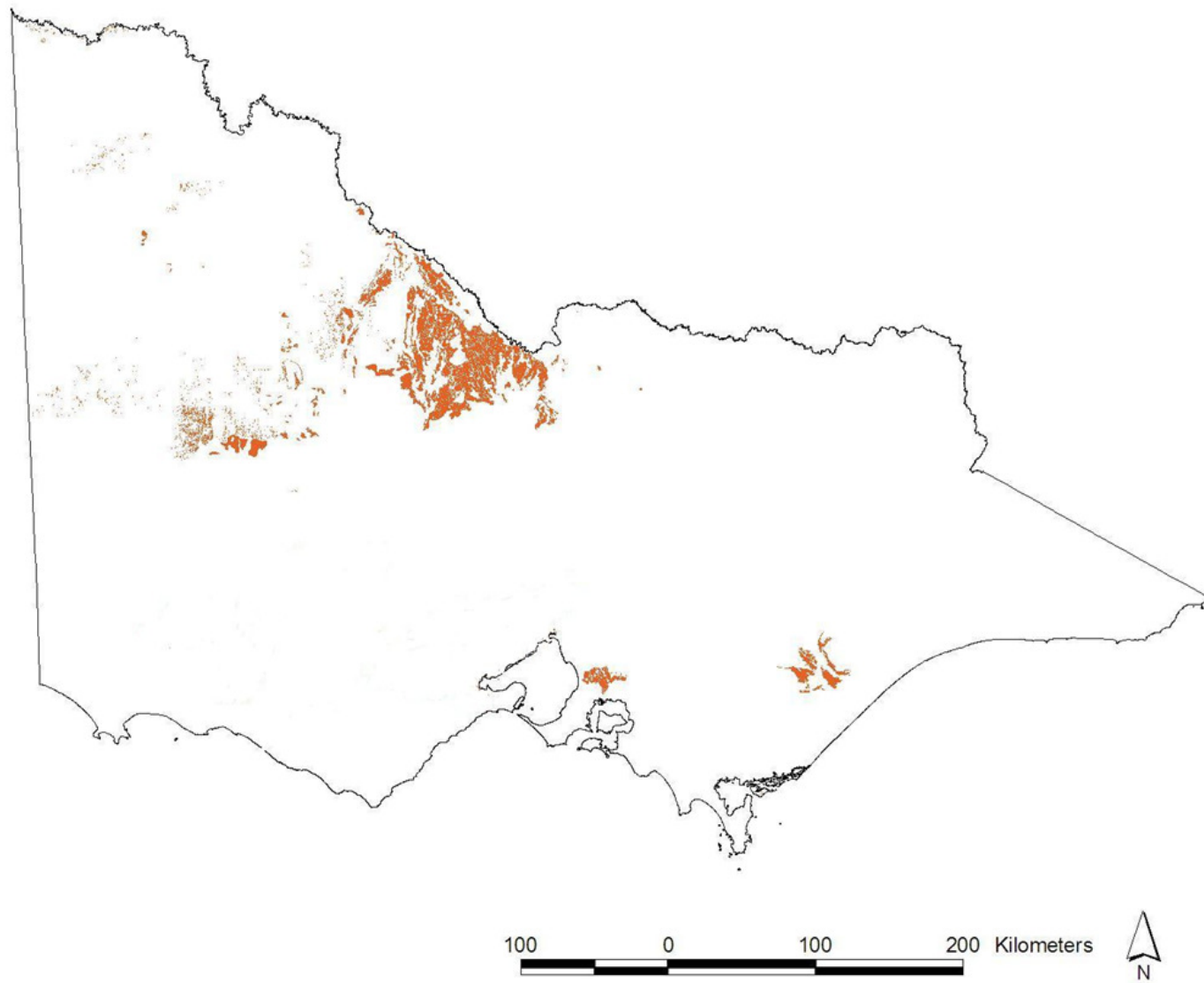


Grassland

Non-Themeda dominated Grassland Causal Model (EVD21 Alluvial Plains Grassland)



EVD 21 Alluvial Plains Grassland



A91

6.9. Heathland (EVD2)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.9.1. Drivers

Fire regime: Regeneration in this ecosystem type is fire cued; vegetation composition may irreversibly change in the long term absence of fire (maximum fire interval is 45 years) (Cheal 2010). Fire regime differs with system productivity (recovery takes longer in north-west and less time in far-east), this is reflected in the minimum fire intervals (see table below).

| Heathland type | Maximum fire interval (years) | Min fire interval High severity (years) | Min. fire interval Low severity (years) |
|---|-------------------------------|---|---|
| Heathland excluding NW | 45 | 12 | 12 |
| Heathland in the NW (Big and Little Desert) | 45 | 15 | 15 |
| Where <i>Xanthorrhoea resinosa</i> dominant | 45 | 15 | 8 |

Soil: Soils are sandy and strongly leached. The key feature of soils in this ecosystem type is their extremely poor nutrient status.

Rainfall: Heathlands occur under a very wide range of rainfall and climate regimes. There is also a wide variation in seasonal soil moisture, which may be dry to very dry in summer and waterlogged in winter.

Past landuse: Some clearing for agriculture, though this has been minimal due to very low nutrient status of soils. Other land use included commercial sand and gravel extraction and urban development.

Ecosystem productivity: Productivity is low; this ecosystem type typically has very low growth and decomposition rates.

6.9.2. Threat Agents

Weed propagules: Because of the low nutrient status of soil there is generally low weed abundance in this ecosystem type. Perennial Veldt Grass is known to occur in the Little Desert National Park, but is associated with disturbance, mainly at the boundary of the park (Parks Victoria 1996). Coastal wattle (*Acacia longifolia* var. *sophorae*), Boneseed (*Chrysanthemoides monilifera*), various species of pine tree, Coast Tea-tree (*Leptospermum laevigatum*), Sweet Pittosporum (*Pittosporum undulatum*), Giant Honey Myrtle (*Melaleuca armillaris*), Green Honey Myrtle (*Melaleuca diosmifolia*), Wirilda (*Acacia retinoides*) and Myrtle Wattle (Western Australian province) (*Acacia myrtifolia*) are of potential concern in the Angelsea Heath (Parks Victoria 2002).

Recreational activities: These include the use of mountain bikes, trail bikes and cars (including four wheel drives), horse riding, bushwalking, camping and picnicking. These activities can result in soil compaction, disturbance and erosion, and the introduction and spread of weeds and pathogens (including *Phytophthora*, see below). Firewood collection occurs in some parks (may be legal or illegal); this reduces the habitat for ground-dwelling animals (mammals, birds, reptiles and invertebrates).

Illegal activities: These include the theft of flora and fauna (e.g. orchids, herbs and parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: The most important impact of climate change on these systems is likely to be increased drought and increased bushfire risk, which may increase fire frequency.

Inappropriate fire regime: The interval between fires may be too long (greater than 45 years) or too short (less than 8, 12 or 15 years depending on the heathland type, see above). Some species may also be sensitive to the time of year that fire occurs.

Inappropriate fire management & suppression methods: These can include the creation of fire breaks/access tracks in vegetation types that are sensitive to disturbance (where natural recovery is unlikely and/or restoration is difficult), or in areas that may already be highly fragmented (which is often the case in this ecosystem type). It may also include the use of fire retardants and wetting agents and foams. The impacts of fire breaks and access tracks include habitat loss and fragmentation (increasing edge effects), soil erosion (increased turbidity and sedimentation of waterways), soil compaction (from the use of heavy machinery) and weed invasion. They create a barrier to migration for native fauna and increased passage way for introduced pest plants and animals and plant pathogens. In vegetation communities that have naturally low nutrient levels (such as this ecosystem type) fire retardants, wetting agents and foams may provide conditions favourable for weed growth (sulphate-based retardants should be used in preference to those containing phosphate).

Phytophthora: *Phytophthora cinnamomi* is a water mould that attacks the root systems of susceptible native plant species, causing plant mortality. This can change the composition and structure of native vegetation communities, and result in the loss of habitat for dependent fauna. Rainfall, temperature and soil characteristics determine the distribution of Phytophthora (warm, wet soils with impeded drainage are ideal). Susceptible plant families are Proteaceae (e.g. *Grevillea*, *Hakea*), Fabaceae (peas), Dilleniaceae (e.g. *Hibbertia*) and Epacridaceae (heaths) (DSE 2008). Phytophthora has been recorded in a number of parks with this ecosystem type (e.g. Lower Glenelg, Grampians, Wilsons Promontory national parks).

Past clearing: Some clearing for agriculture, though this has been minimal due to very low nutrient status of soils. Other land use included commercial sand and gravel extraction and urban development.

Adjacent landuse: Agriculture and urban development in surrounding areas are a potential source of weed propagules, and runoff containing nutrients, pesticides and herbicides. Urban stormwater runoff may also contain sewage effluent and pollutants (e.g. heavy metals). The modification of remnant vegetation on adjacent private land may also increase the effects of habitat loss and fragmentation.

Introduced predators: Includes foxes and cats.

6.9.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions and whether there are weed management strategies in place. Pest plant invasion is limited in this ecosystem type by the low fertility of the sandy soils. However, the use of phosphate-based fire retardant has potential to possibly increase pest plant establishment and survival in areas where the low fertility of the sands is currently a limiting factor in the survival of such species (Parks Victoria 1996). Internal fragmentation (within the park) from roads and tracks may also increase opportunities for weed invasion.

Soil degradation/disturbance/bare ground: Soil degradation includes compaction, disturbance and erosion, the creation of bare ground and altered hydrology. Erosion has impacts on soil water storage capacity and water quality. Bare ground provides the opportunity for the establishment of weed species. Soil disturbance, erosion, and bare ground may result from recreational activities, illegal activities (especially off-track activities) and fire. Soil compaction and increased runoff can become an issue in areas that see heavy use.

Fire too frequent (interval too short): May result in loss of species where the inter-fire interval not adequate to allow species to reach reproductive maturity and produce viable amounts of seed (loss of these species in the seed bank). Resultant changes in vegetation composition and structure, and loss of habitat for dependent fauna.

Fire not frequent enough (interval too long): Fire intervals greater than 45 years may result in irreversible change to vegetation community composition and structure. Possible loss of fire adapted species. If long-lived non-heathland species are present (e.g. *Banksia serrata*, *Leptospermum trinervium*) these may begin to dominate. In the absence of fire heathland may change into another ecosystem type.

Dieback: Dieback is the premature and rapid decline and death of individual plants, and has a number of root causes which are likely to interact. In this ecosystem type the most common cause for dieback is *Phytophthora* (see above).

Elevated soil nutrients: Soil nutrient may become elevated from the use of phosphate-based fire retardants or by nutrient laden runoff. Soil in this ecosystem type naturally has very low nutrients, nutrient enrichment can cause the decline of native species and weed invasion.

Habitat loss: Some clearing for agriculture, though this has been minimal due to very low nutrient status of soils. Other land use included commercial sand and gravel extraction and urban development. Land clearing has resulted in the loss and fragmentation of this ecosystem type. Remaining habitat may also be under pressure from degrading processes which can contribute to further habitat loss (e.g. nutrient enrichment, soil compaction and disturbance, altered hydrology and weed invasion).

Fragmentation: Heathlands in some parks (e.g. Angelsea Heath) are affected by internal fragmentation, resulting from a high number of tracks and roads (may be recognised or informal). Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions. Tracks and roads may also facilitate the dispersal of pest plants and animals and plant pathogens, and increase the extent of soil erosion and altered hydrology.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.9.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion. The maintenance of low nutrient status is important in this ecosystem type, nutrient enrichment may occur with the use of phosphate-based fire retardants or from nutrient-containing runoff.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Fire breaks and management tracks: On the west coast these are already significant, will become more so as there is a recognised need for more protection of coastal settlements. These contribute to the effects of fragmentation (barrier to of flora and fauna movement), and may lead to soil erosion, increased turbidity of waterways, weed invasion and increased passage for pest animals and plant pathogens such as *Phytophthora*.

Restoration: Different restoration methods applied to the different ecosystems. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas. Restoration in this ecosystem type may include rehabilitation of walking and management tracks.

Phytophthora containment & hygiene measures: Containment and hygiene measures are used to minimise the spread of *Phytophthora cinnamomi*. Procedures include management (or minimization) of movement of people, vehicles, equipment and other materials from infested into uninfested sites, and may include wash-down facilities. Other considerations

include road placement, movement of gravel, road grading operations, drainage and management of vehicle tracks and fire operations.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.9.5. Resultant Habitat Structure

Heath: hard, small leaved plants, generally between 1-2 m tall. Include species from the Epacridaceae, Proteaceae, Papilionaceae and Myrtaceae families, e.g. *Allocasuarina*, *Leptospermum*, *Epacris*, *Hakea*, *Banksia*, *Melaleuca* species. Also *Xanthorrhoea* in some heathlands.

Tree species: occasional, more common in damp heathlands, less than 15m tall, e.g. *Eucalypt* spp., *Allocasuarina verticillata* and/or *Acacia retinodes*.

Ground cover: Sedges, lilies, rope-rushes, prostrate shrubs and herbs, orchids

6.9.6. References

Cheal, D. (2010). *Growth stages and tolerable fire intervals for Victoria's native vegetation data sets*. Fire and Adaptive Management Report No. 84. Department of Sustainability and Environment, East Melbourne.

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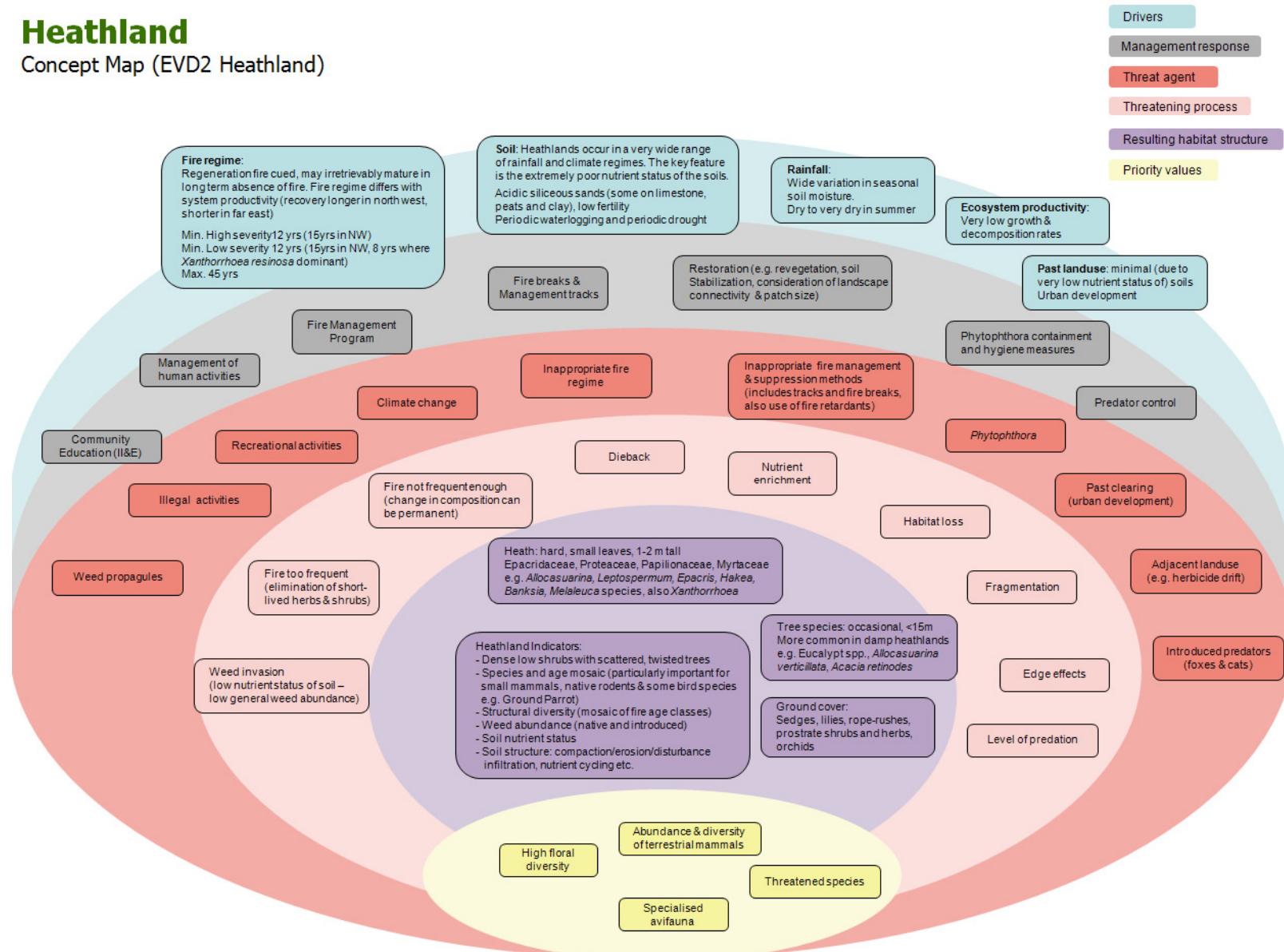
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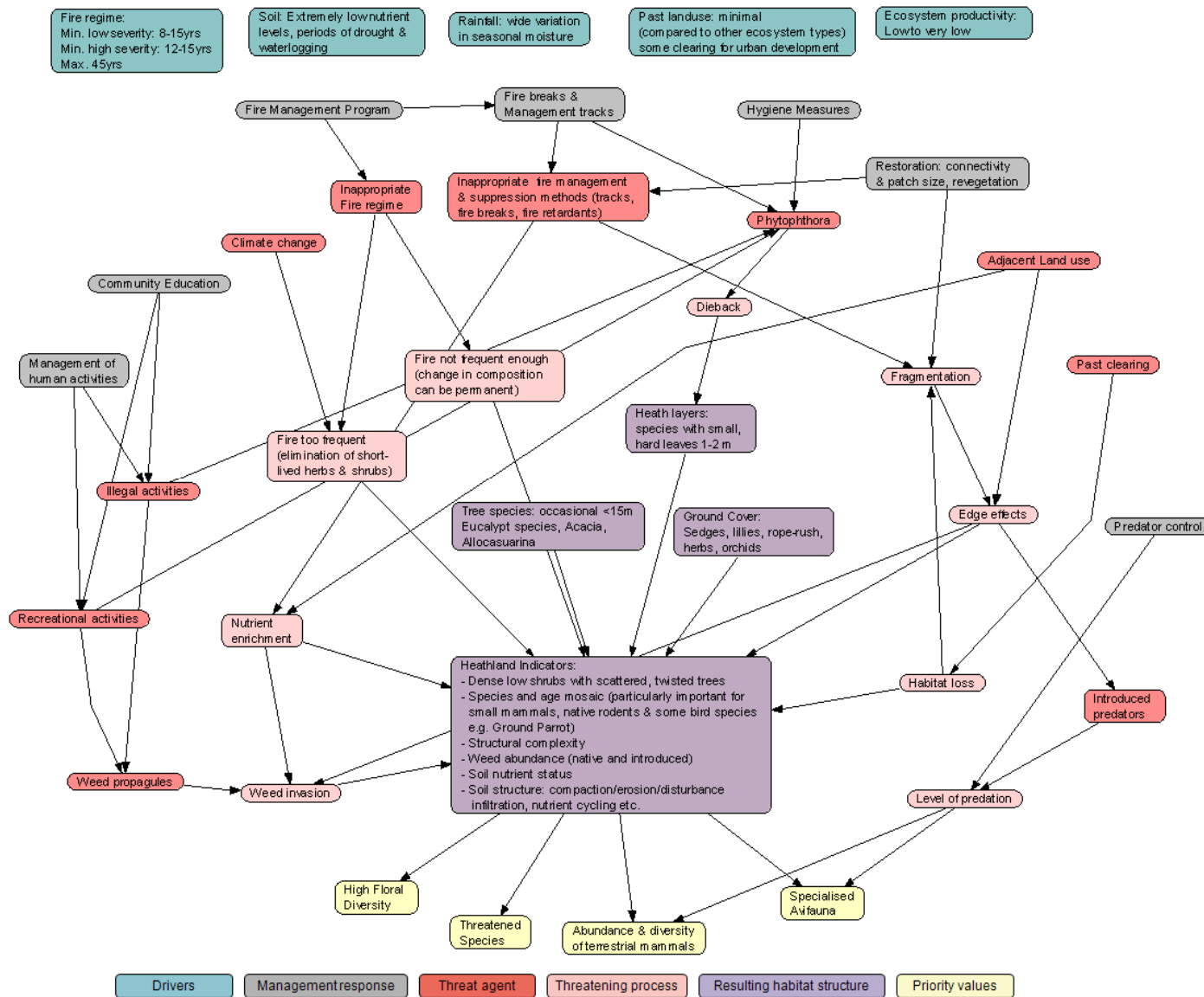
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Heathland

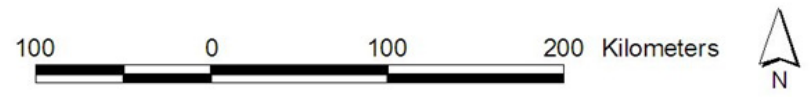
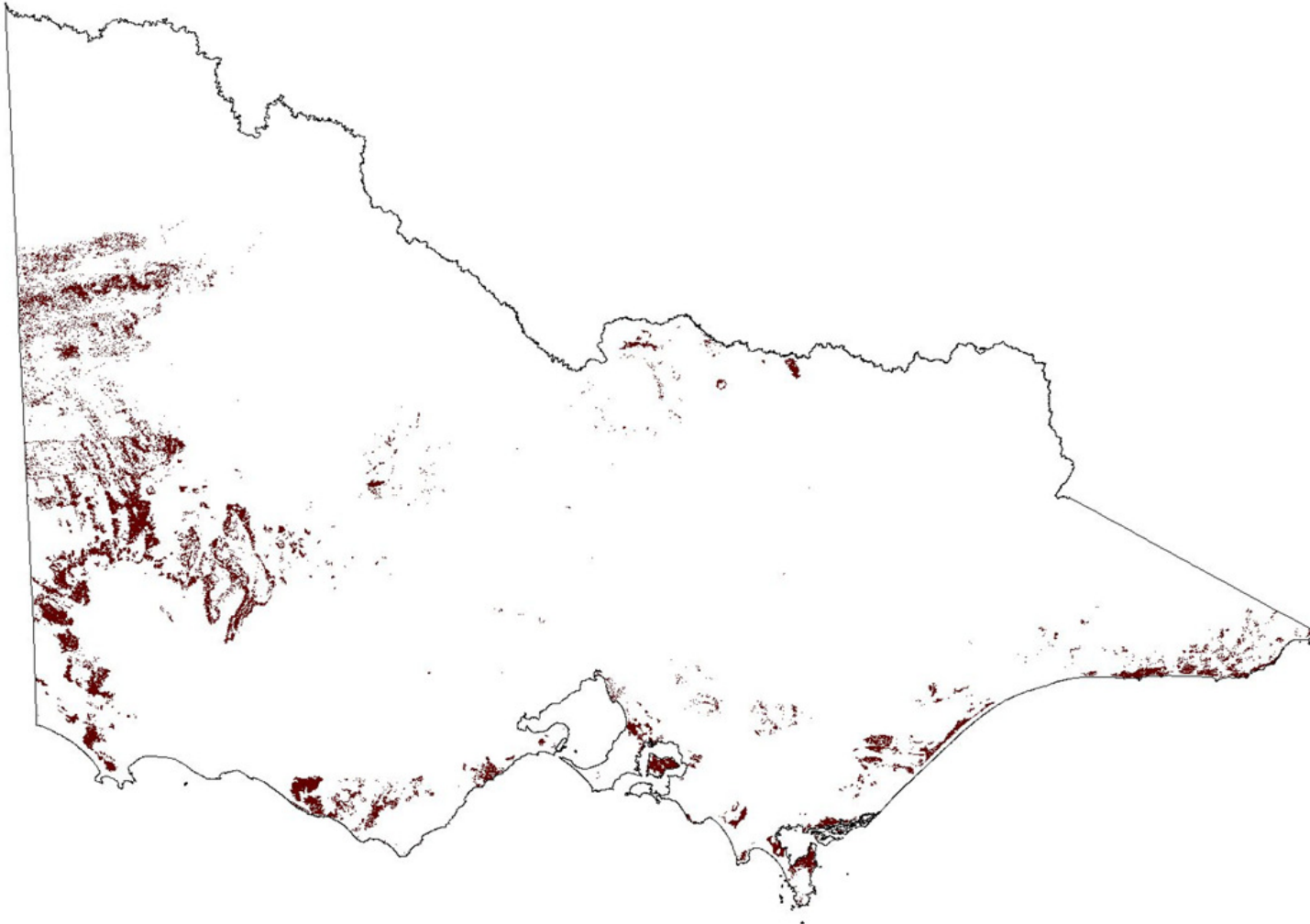
Concept Map (EVD2 Heathland)



Heathland (EVD2) Causal Model



EVD 2 Heathland (Sands)



A102

6.10. Mallee (EVD29, EVD30, EVD31, EVD32)

Includes EVD29 (Saltbush Mallee), EVD30 (Hummock-grass Mallee), EVD31 (Lowan Mallee) and EVD32 (Broombush Whipstick). Excludes heathlands, semi-arid woodlands and inland waters.

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.10.1. Drivers

Fire regime: Varies according to EVD (see below) (from Cheal 2010).

EVD29: Very rarely flammable, may take many decades to recover from fire, rare fires required to maintain canopy, but typical species do not require fire for regeneration.

EVD30: Flammable in all seasons, fast, moderate severity fires, but many fire refuges due to fuel discontinuity. Many species require fire for regeneration, but only occasionally as growth rates are very slow.

EVD31: Flammable in all seasons, moderate severity fires, fuel continuity (and therefore refuge) varies. Many species require fire for regeneration, but only occasionally as growth rates are very slow.

EVD32: Flammable except for winter, rapid fire often of high severity, few refuges. Many species require fire for regeneration, long term absence of fire may degrade this ecosystem type.

| EVD | Maximum fire interval (yrs) | Minimum fire interval (yrs) |
|-------------------------|------------------------------------|------------------------------------|
| 29 Saltbush Mallee | 200 | 40 |
| 30 Hummock-grass Mallee | 90 | 25 |
| 31 Lowan Mallee | 65 | 20 |
| 32 Broombush Whipstick | 90 | 20 |

Soil: Generally infertile, sandy and relatively fragile. Soils also potentially very mobile, biological soils crusts are very important in protecting soils from erosion.

| EVD | Occurs on |
|----------------------------|--|
| 29 Saltbush Mallee | calcareous dunefields (more saline older dunes) |
| 30 Hummock-grass Mallee | |
| 31 Lowan Mallee | siliceous sands (younger sand dunes) |
| 32 Broombush Whipstick | sandstone ridges and rises |

Rainfall: Low with high inter-annual variation, average between about 250 – 400 mm per year.

Past landuse: This ecosystem type was cleared for agriculture (wheat and sheep farming) and urban development.

Ecosystem productivity: Low due to low soil fertility and generally low and highly variable rainfall.

6.10.2. THREAT AGENTS

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native). Typical weed species include agricultural weeds such as Silver-leaf Nightshade, Wild Garlic, Prairie Groundcherry and Camelthorn. Environmental weeds include Bridal Creeper, African Box-thorn, Cactus species, Golden Dodder, Horehound, Peppercorn/ Weeping Willow and exotic annual grasses (Parks Victoria 1996).

Recreational activities: These include driving (2-wheel and 4-wheel driving), picnicking, hiking and camping at designated sites (facilities supplied) and dispersed camping (no facilities).

Illegal activities: These include the theft of flora and fauna (e.g. parrots), rubbish dumping, unauthorized firewood collection, and off-road driving and riding, which can damage and/or remove vegetation and/or the biological soil crust, and cause soil compaction and erosion.

Climate change: The most important impact of climate change on these systems is likely to be increased drought, which will impact on flora and fauna reproduction and recruitment. Climate change may also increase fire frequency and may result in out-of-season fires.

Inappropriate fire regime: Fire interval too long or too short (see fire regimes above).

Inappropriate fire management & suppression methods: These can include the creation of fire breaks/access tracks in vegetation types that are sensitive to disturbance (where natural recovery is unlikely and/or restoration is difficult), or in areas that may already be highly fragmented. It may also include the use of fire retardants and wetting agents and foams. The impacts of fire breaks and access tracks include habitat loss and fragmentation (increasing edge effects), soil erosion, soil compaction (from the use of heavy machinery) and weed invasion. They create a barrier to migration for native fauna and increased passage way for introduced pest plants and animals. Runoff containing fire retardants, wetting agents and foams may have adverse effects in vegetation communities that have naturally low nutrient levels they may provide conditions favourable for weed growth.

Introduced herbivores: Include rabbits and goats.

Overabundant native herbivores: Over-abundant native fauna (may include Western Grey Kangaroos and Red Kangaroos). Probably rely on artificial water supplies within the parks and in adjacent land (farm dams etc).

Past clearing: This ecosystem type was extensively cleared for agriculture (wheat and sheep) and urban development, and is highly fragmented.

Adjacent landuse: May be a source of weed propagules, provide a water and food source for Western Grey Kangaroos and Red Kangaroos.

Firewood collection: Firewood collection occurs within this ecosystem type for use in campfires. Firewood collection reduces available habitat for ground dwelling mammals, birds, reptiles and invertebrates.

Introduced predators: Includes foxes and cats.

6.10.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place.

Increased erosion and movement of soils, degradation of biological soil crust: Land clearing and the introduction of herbivores (managed and feral) have reduced the cover of vegetation and biological soil crusts in this ecosystem type, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Soils in this ecosystem type are potentially very mobile, and biological soils crusts are very important in protecting these soils from erosion. Biological soil crusts also regulate the flow of water into soils and provide sites for the establishment and survival of seedlings (Eldridge 2000). Erosion reduces soil water storage capacity and water quality, and compaction reduces

infiltration and impedes root growth. Bare ground provides the opportunity for the invasion and establishment of weed species. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire.

Increased drought: Increased drought is likely to impact on the frequency reproductive events and the rate of successful recruitment in this ecosystem type, leading to a decrease in vegetation cover. Biological soil crusts may also be affected by drought due to a decrease in the number of days that are suitable for growth, which is likely to make them more vulnerable to disturbance (slower to recover).

Fire too frequent (interval too short): Fire too frequent (see fire regimes above), some species in these systems are sensitive to fire. May result in loss of species where the inter-fire interval not adequate to allow species to reach reproductive maturity and produce seed (loss of these species in the seed bank). Also may result in changes in vegetation composition and structure, and loss of habitat for dependent fauna.

Overgrazing: This ecosystem type is sensitive to grazing, post-grazing regeneration is poor. Seedlings may require protection (fenced exclosures) from rabbit and kangaroo grazing. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground).

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, dust (and other particulate deposition), insect attack, predator incursions, nutrient enrichment and soil disturbance. Sand humping has been observed at the edge of reserves, wind is predominantly from the west and therefore the western edge is most vulnerable to this effect. Where there is sand build up there tends to be less cover of biological soil crusts and more weeds, sand also contributes to nutrient enrichment (wind dumping of enriched soils). Nutrients are coming mainly from crop fertilization, and sheep manure and feed (Duncan et al. 2008).

Elevated soil nutrients: Soil nutrient may become elevated as a result of surrounding land use, derived from nutrient laden runoff and/or dust (see above).

Habitat loss: Past land clearing has resulted in the loss and fragmentation of this ecosystem type. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Loss of woody debris: This is important in this ecosystem type as they are low productivity systems and generate woody debris very slowly. Woody debris provides habitat and food sources for ground dwelling mammals, birds, reptiles and invertebrates, and is removed by fire and with firewood collection.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.10.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Fire breaks and management tracks: These contribute to the effects of fragmentation (barrier to flora and fauna movement), and may lead to soil erosion and weed invasion.

Grazing management: Grazing management may target introduced herbivores (rabbits and goats) and/or overabundant native herbivores (kangaroos). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora). In this ecosystem type grazing management is required in areas where grazing pressure is sufficient to suppress the regeneration of

woody vegetation. The increased availability of water in these systems has allowed kangaroo populations to be sustained at artificially high densities during dry periods. Diversity and abundance of native plant species may need to be monitored to determine the carrying capacity for kangaroos. Limiting access to water (fencing or decommissioning water sources within parks, fencing at park boundary to limit access to water and pasture) helps to control goat and kangaroo populations. Kangaroo populations are also controlled by culling. Rabbit management can include poisoning, ripping, fumigation, shooting and biological control.

Restoration: Different restoration methods are applied to the different ecosystem type. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. Revegetation may also be used to improve connectivity between areas of remnant habitat. Specific actions may be taken to stabilize soil in actively eroding areas. Restoration in this ecosystem type may include fenced exclosures.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.10.5. Resultant Habitat Structure

Saltbush/Hummock-grass Mallee: Dumosa Mallee (*E. dumosa*), Oil Mallee (*E. oleosa*), Grey Mallee (*E. socialis*) and Slender-leaf Mallee (*E. leptophylla*). Understorey: low succulent saltbushes, some Chenopods and hummock grasses (includes *Triodia* spp.).

Lowan Mallee: Yellow Mallee (*E. incrassata*), Slender-leaf Mallee (*E. leptophylla*), Grey Mallee (*E. socialis*) and Desert Stringybark (*E. arenacea*). Understorey: rich in heath spp. (high nectar and seed production), some hummock grasses.

Broombush Whipstick: Grey Mallee (*E. socialis*), Dumosa Mallee (*E. dumosa*), Yellow Mallee (*E. incrassata*) and Slender-leaf Mallee (*E. leptophylla*), understorey typically dominated by the tall shrub *Melaleuca uncinata*.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire).

6.10.6. References

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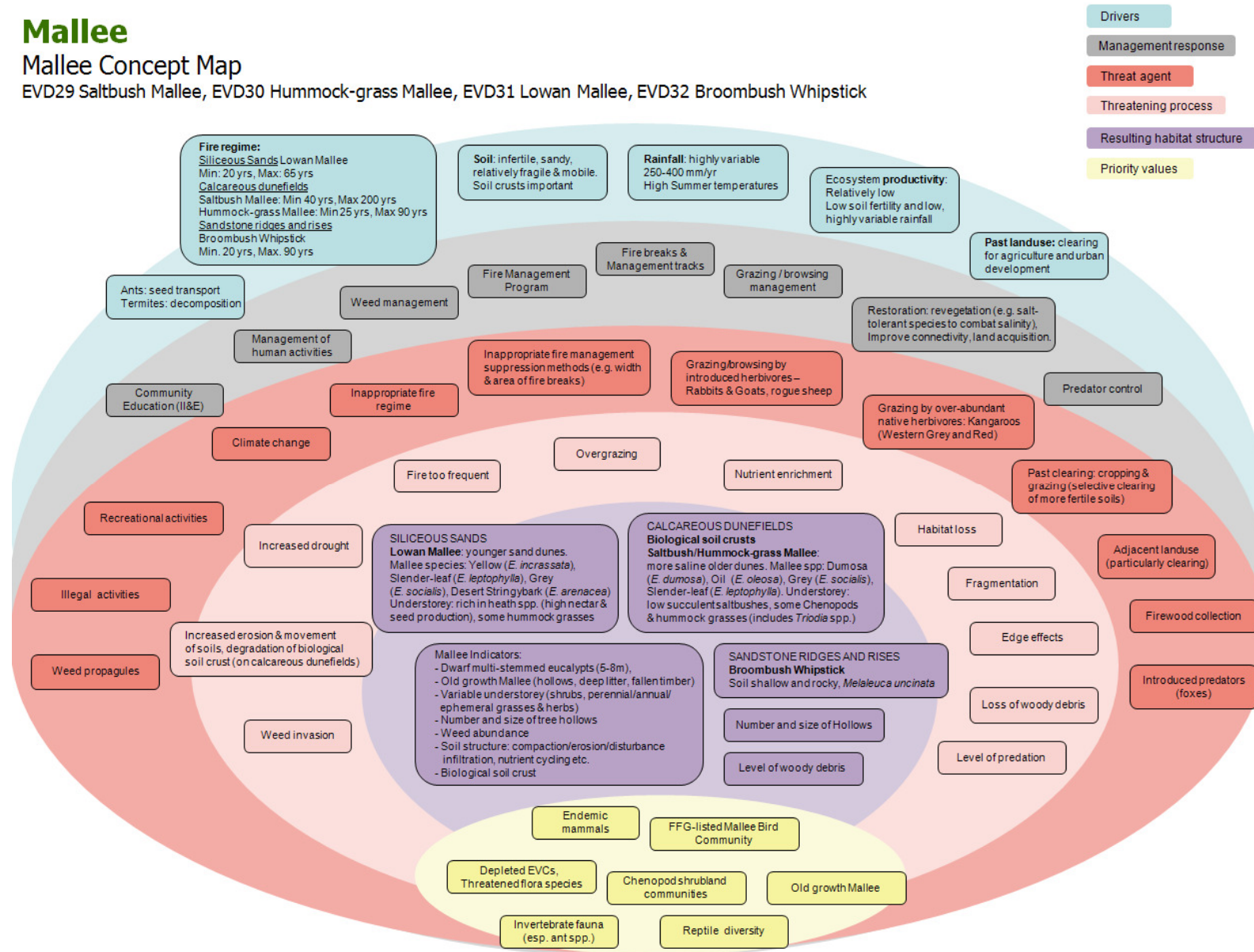
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Mallee

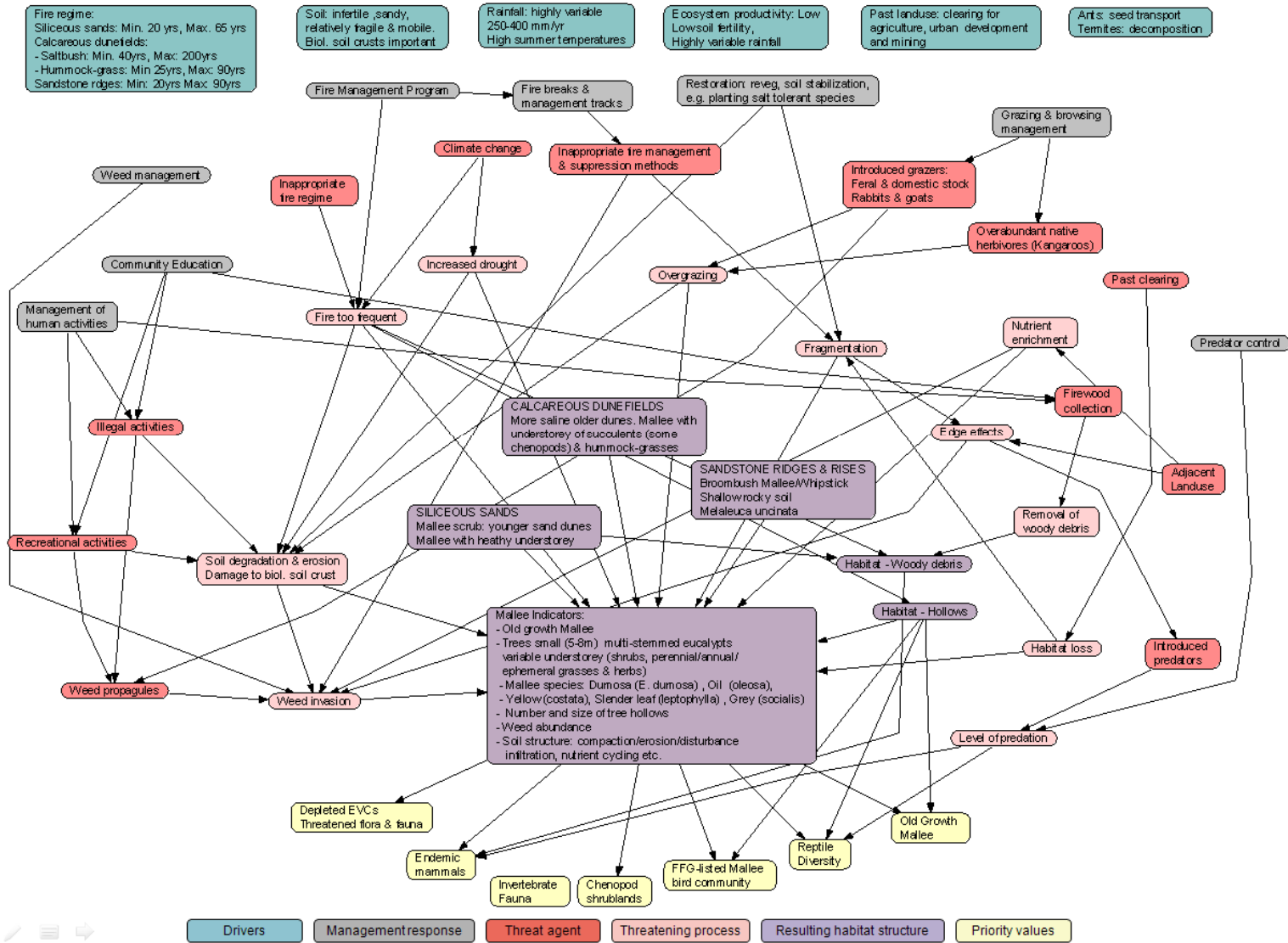
Mallee Concept Map

EVD29 Saltbush Mallee, EVD30 Hummock-grass Mallee, EVD31 Lowan Mallee, EVD32 Broombush Whipstick

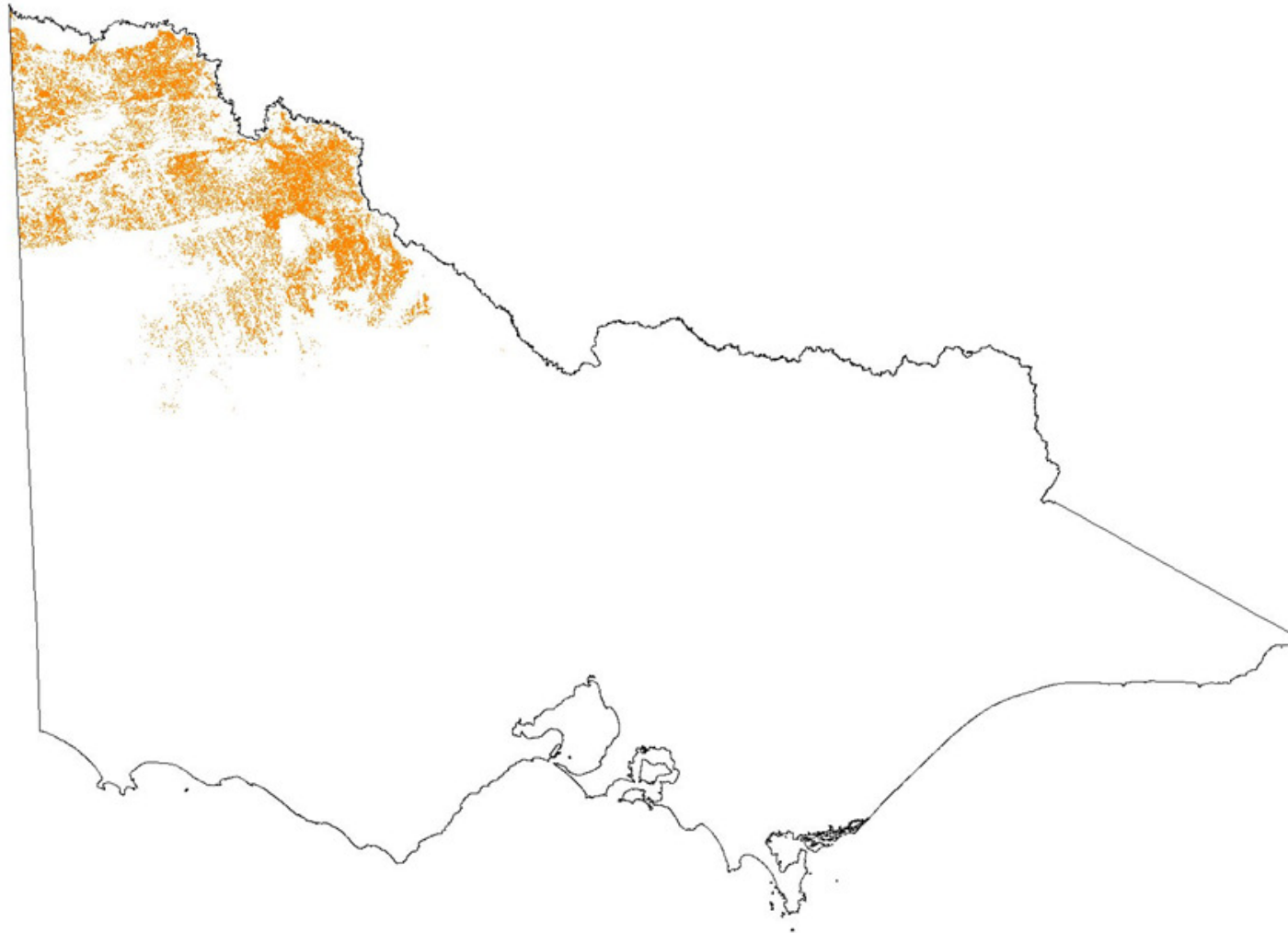


Mallee

Mallee Causal Model (EVD29 Saltbush Mallee, EVD30 Hummock-grass Mallee, EVD31 Lowan Mallee, EVD32 Broombush Whipstick)



EVD 29 Saltbush Mallee

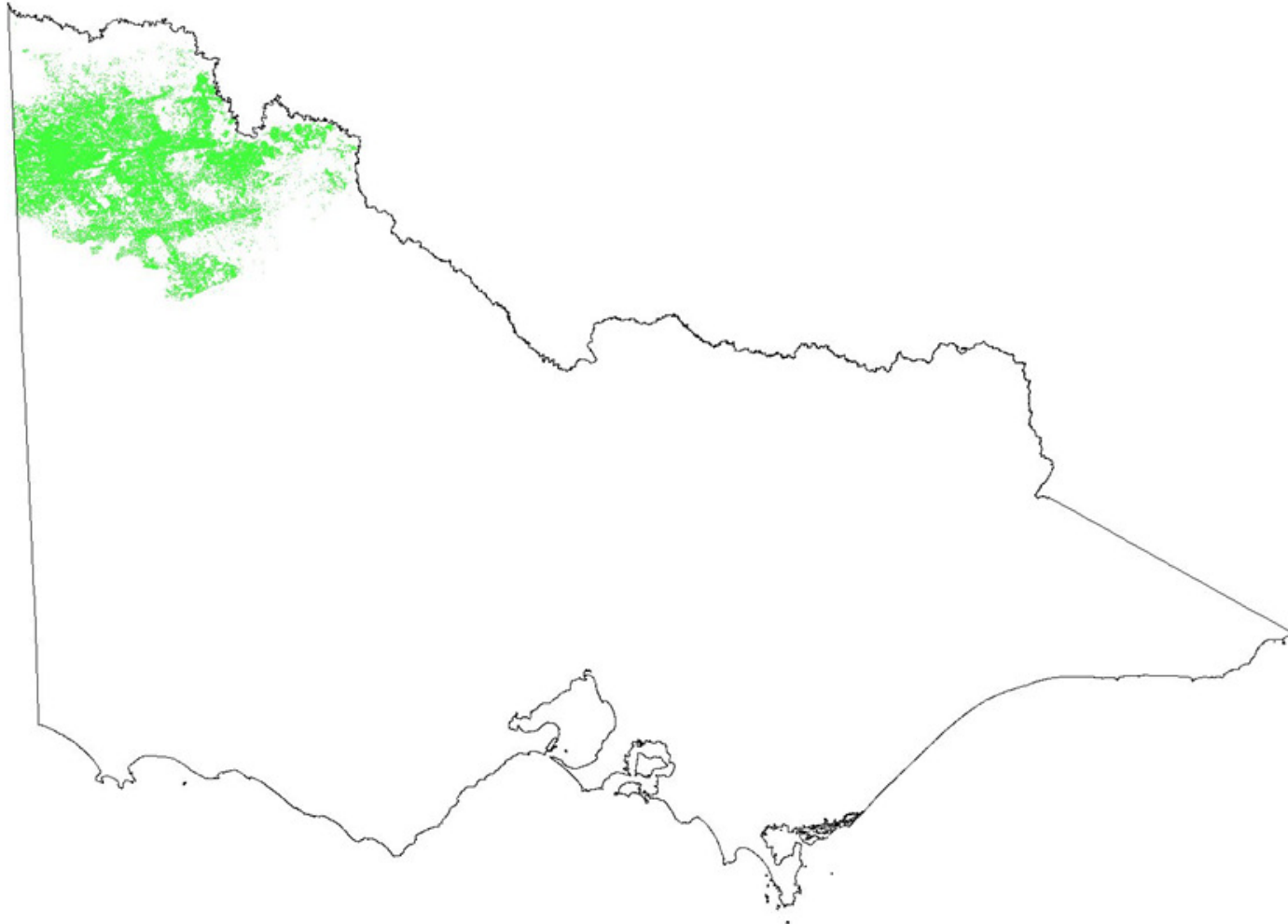


100 0 100 200 Kilometers



A113

EVD 30 Hummock-grass Mallee



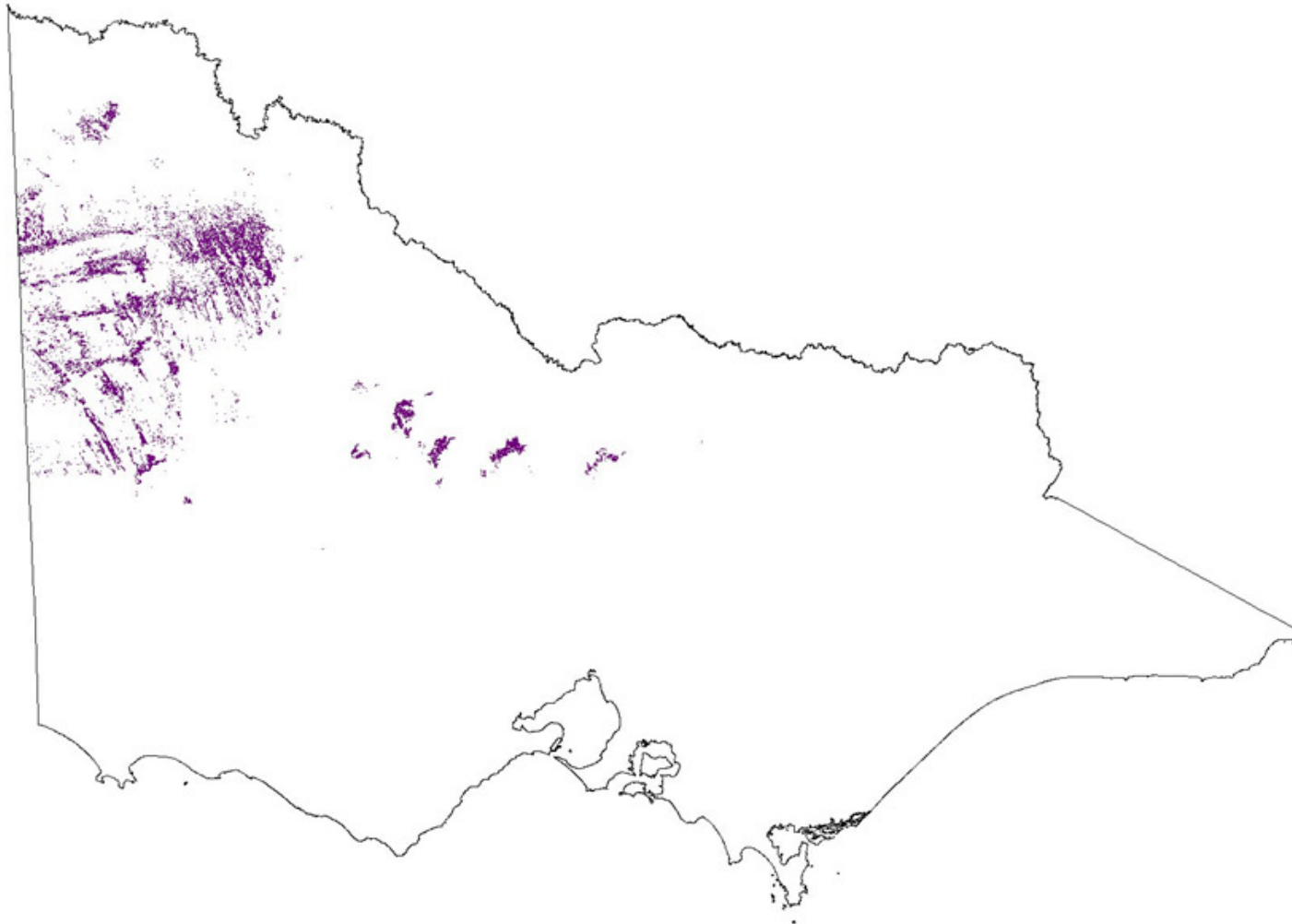
A114

EVD 31 Lowan Mallee



A115

EVD 32 Broombush Whipstick



100 0 100 200 Kilometers



A116

6.11. Alps: Alpine-Subalpine (EVD14, EVD15, EVD16)

Includes EVD14 (High Altitude Shrubland/Woodland), EVD15 (High Altitude Wetland) and EVD16 (Alpine Treeless).

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.11.1. Drivers

Fire regime: The EVDs that make up this ecosystem type are flammable only in very rare conditions (e.g. after extended droughts). Few species are geared to regenerate post-fire, and the habitats are usually damaged by fire. The EVDs have different fire requirements, as outlined below (Cheal 2010).

| EVD | Maximum fire interval (yrs) | Min fire interval High severity (yrs) | Min. fire interval Low severity(yrs) | Notes |
|--------------------------------------|--|---------------------------------------|---------------------------------------|---|
| 14 High Altitude Shrubland/ Woodland | 125 (though fires at 150 yrs likely to have little adverse impact) | 50 | 35 | Take many decades to recover, few species geared to regenerate after fire which favours shrubs over herbs. |
| 15 High Altitude Wetland (peatlands) | Infinite | 90 (peat burn) 40 (peat not burnt) | 90 (peat burn) 40 (peat not burnt) | May take centuries to recover after fire, habitat damaged by fire, prone to erosion for few years post fire. |
| 16 Alpine Treeless | 120 | 55 | 55 | Take many decades to recover from fire, fire favours shrubs over herbs (changes vegetation structure to more shrubby) |

Soil: Peat and deep alpine humus soils. Latter has high infiltration, high storage capacity; vulnerable to erosion due to open structure and high velocity/high volume flows, vegetation cover protects soils and maintains high infiltration.

Precipitation: High, annual average usually above 1,000mm; falls as snow in the colder months.

Elevation: Confined to the mountainous areas in the east of the state, usually above 1,300 metres.

Past landuse: The Australian Alps have had a number of different land uses. The most intensive of these include the grazing of livestock (mostly of cattle and sheep, and also horses), mining, and the development of infrastructure for hydroelectricity development and the ski industry. The incidence of fire increased with European settlement, especially in the period from the mid to late 1800s (Banks 1989, Zylstra 2006).

Ecosystem productivity: Relatively low, due to low temperatures and short growing season, plant growth and succession are slow compared to lower elevation vegetation communities.

6.11.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities (hiking, camping and horse riding) and herbivores (introduced and native). Sources for weed propagules include current infestations, resorts and surrounding, lower elevation forest. Weed species include Grey Sallow Willow (*Salix cinerea*), Sheep Sorrel (*Acetocella vulgaris*), Cat's Ear (*Hypochoeris radicata*), Yorkshire Fog (*Holcus lanatus*), White Clover (*Trifolium repens* var. *repens*), Blackberry (*Rubus fruticosus* spp. agg.) and English Broom (*Cytisus scoparius*). Recent serious weed invasions include two species of Hawkweed, Orange hawkweed (*Hieracium aurantiacum*) and King Devil Hawkweed (*Hieracium piloselloides*).

Recreational activities: These include the use of mountain bikes, motor bikes and cars (includes four-wheel driving in some areas), and horse riding, hiking and camping.

Illegal activities: These include the theft of flora and fauna, littering, unauthorized firewood collection, and off-road driving, riding and hiking, which can damage and/or remove vegetation and cause soil compaction and erosion.

Climate change: Alpine-subalpine areas are vulnerable to climate change. With increasing temperatures the altitudinal distribution of vegetation is projected to shift to higher elevations in mountainous regions, ecosystems that occur on mountain tops (such as the Australian Alps) have limited opportunity for migration, and hence are particularly vulnerable. Climate change impacts include invasion of shrubs and trees into treeless vegetation, which has already been observed (Wearne and Morgan 2001); and increased drought, which will be likely to increase fire frequency and decrease runoff. Many exotic plant species have been excluded from the Australian Alps by frost and snow, and the short growing season that limits opportunities to establish. Climate change is likely to alleviate temperature constraints, and

lengthen the growing season. Reduced snow cover is also likely to have impacts on fauna and flora species.

Inappropriate fire regime: Fire too frequent (see above), high severity fire may also be an issue, as these tend to be more widespread and leave fewer unburnt patches from which an area can be recolonised. This is particularly important in Sphagnum-dominated wetlands, as Sphagnum recolonises by expanding from unburnt patches.

Inappropriate fire management & suppression methods: These can include the creation of fire breaks/access tracks in vegetation types that are sensitive to disturbance (where natural recovery is unlikely and/or restoration is difficult, e.g. peatlands), or in areas that may already be highly fragmented, or rare and restricted (this ecosystem type). The impacts of fire breaks and access tracks include habitat loss and fragmentation (increasing edge effects), soil erosion (increased turbidity and sedimentation of waterways), soil compaction (from the use of heavy machinery) and weed invasion. Runoff containing fire retardants, wetting agents and foams may have adverse effects on aquatic plant and animal species, in vegetation communities that have naturally low nutrient levels (e.g. peatlands) they may provide conditions favourable for weed growth.

Introduced herbivores: Includes horses, hares and deer; there may also be some stray cattle (which may be grazing in adjacent land, usually state forest).

Water diversion: Water diversion for hydroelectricity generation is an issue in some parks (e.g. on the Bogong High Plains in the Alpine National Park) and diverts water from wetlands and other vegetation communities. Aqueducts that cut across peatlands drain the part of the peatland that occurs above the aqueduct, and reduce the supply of water to the part of the peatland below the aqueduct (Tolsma and Shannon 2007).

Past land management: Disturbance in this ecosystem type has come from grazing of livestock (mostly of cattle and sheep, and also horses), mining, and the development of infrastructure for hydroelectricity development and the ski industry. Regular and widespread burning of the alpine and subalpine vegetation was part of established land management practices, undertaken by graziers to encourage a flush of new grass growth (Good 1992). Grazing and increased fire have reduced the vegetation cover, providing opportunities for weed invasion and erosion.

Introduced predators: Includes foxes, cats and wild dogs.

6.11.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions, and whether there are weed management strategies in place. Australia's alpine landscapes have a low number of weed species and low weed biomass compared to lowland systems (McDougall 2003); this is due to the more extreme climatic conditions that occur at high elevations (McDougall 2005, Bear et al. 2006). However, there are indications that the number and abundance of introduced plant species is increasing in the Australian Alps (Johnston and Pickering 2001, McDougall et al. 2005, Bear et al. 2006). A total of 128 species have invaded these habitats in Victoria; most were introduced unintentionally, some for rehabilitation and amenity plantings in alpine resorts (McDougall 2003, McDougall et al. 2005).

Soil degradation/disturbance/bare ground: Alpine and subalpine soils are highly erodible, due to their open porous structure, when not adequately covered by native vegetation (Gibbons and Rowan 1993). The loss of vegetation cover and compaction of the soil due to trampling can reduce the infiltration rate and hence increase the potential for surface runoff and erosion. The removal of vegetation also decreases the interception capacity of plant cover, increasing the energy of impacting raindrops, and increasing the ability to remove soil particles (Hardie 1993). Soil disturbance in this ecosystem type is particularly important as, due to the low temperatures and short growing season, revegetation of bare ground is very slow. The creation of bare ground provides opportunities for weed invasion and further erosion.

Increased drought: Climate change is likely to increase the frequency and severity of droughts. Increased drought will decrease water supply wetland systems, and also the surrounding vegetation communities. Increased drought is also likely to contribute to more frequent and more severe fire.

Fire too frequent (interval too short): Few species in this ecosystem type are geared to regenerate post-fire, and the different habitat components (EVDs) are usually damaged by fire; they can take between many decades (High Altitude Shrubland/Woodland, Alpine Treeless) to centuries (High Altitude Wetland) to recover after fire. Fire in the Australian Alps prior to European settlement was infrequent, with estimates of less than one high-intensity fire per century and smaller, low intensity fires occurring every 10-70 years (Costin et al. 1959, Banks 1989). Fire is not a requirement for the maintenance of any alpine vegetation community (Kirkpatrick 1983; Wahren et al. 2001), though there is a small group of species that may depend on large-scale fire for regeneration (Williams et al. 2008). *Derwentia nivea*, *Barbarea grayi* and *Pelargonium helmsii* were thought to be extremely rare, but have had a pronounced fire response (Walsh and McDougall 2005).

Grazing & Trampling: Grazing in this ecosystem type contributes to soil erosion and reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Trampling by introduced grazers also cause soil compaction, which decreases infiltration and increases the likelihood of overland flow and therefore erosion. Soil disturbance in this ecosystem type is particularly important as, due to the low temperatures and short growing season, revegetation of bare ground is very slow. This creates opportunities for weed invasion and further erosion. Wetlands are particularly susceptible to the effects of trampling, as they are prone to mechanical damage (peaty soils having low mechanical strength) and erosion.

Habitat loss: Past land management has resulted in the loss and fragmentation of this ecosystem type, from roading, infrastructure for ski industry (resorts development, car parks, ski runs, etc), hydroelectricity generation (including two water storages and 35km of aqueducts on the Bogong High Plains), and tourism (walking tracks, tourist facilities). Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: Alpine-subalpine habitats have a naturally fragmented distribution, occurring at the tops of mountains. However, internal fragmentation (within parks) from walking and management tracks, aqueducts and resort development may also be an issue in this ecosystem type.

Edge effects: Edge effects may occur in this ecosystem type in response to roads and walking tracks, resorts and tourist facilities, it may result in increased exposure to weed propagules and soil disturbance (bare ground, erosion, compaction).

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species (introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant). The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species. This ecosystem type supports the FFG-listed Mountain Pygmy Possum, which is vulnerable to predation by foxes and cats.

6.11.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weed management in this ecosystem type may include herbicides, manual removal and/or biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion. Weed management in this ecosystem type includes programs to control English Broom, Grey Sallow Willow and Hawkweed.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals. Fire management in this ecosystem type is focused on suppression activities.

Fire breaks and management tracks: Fire breaks and management tracks contribute to the effects of fragmentation (barrier to of flora and fauna movement), and may lead to soil erosion, increased turbidity of waterways, weed invasion and increased passage for pest plants and animals.

Restoration: Different restoration methods applied to different ecosystem types. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. In this ecosystem type restoration activities may include revegetation, soil stabilization, rehabilitation of fire control lines and specific vegetation communities (e.g. peatlands).

Grazing management: Grazing management in this ecosystem type would target introduced herbivores (mainly deer and horses). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora, soil trampling and erosion).

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site

characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.11.5. Resultant Habitat Structure

Shrubland/Woodland: Tree species include: *E. pauciflora*, *E. mitchelliana*, *E. delegatensis* and *E. dalrympleana*

Grassland: Include tussock grasses, small sedges and a diverse range of herbs.

Heathland: Include shrubby peas, heaths, peppers, wattles and mint-bushes.

Peatlands: Include *Sphagnum*, epacrid and restinaceous shrubs.

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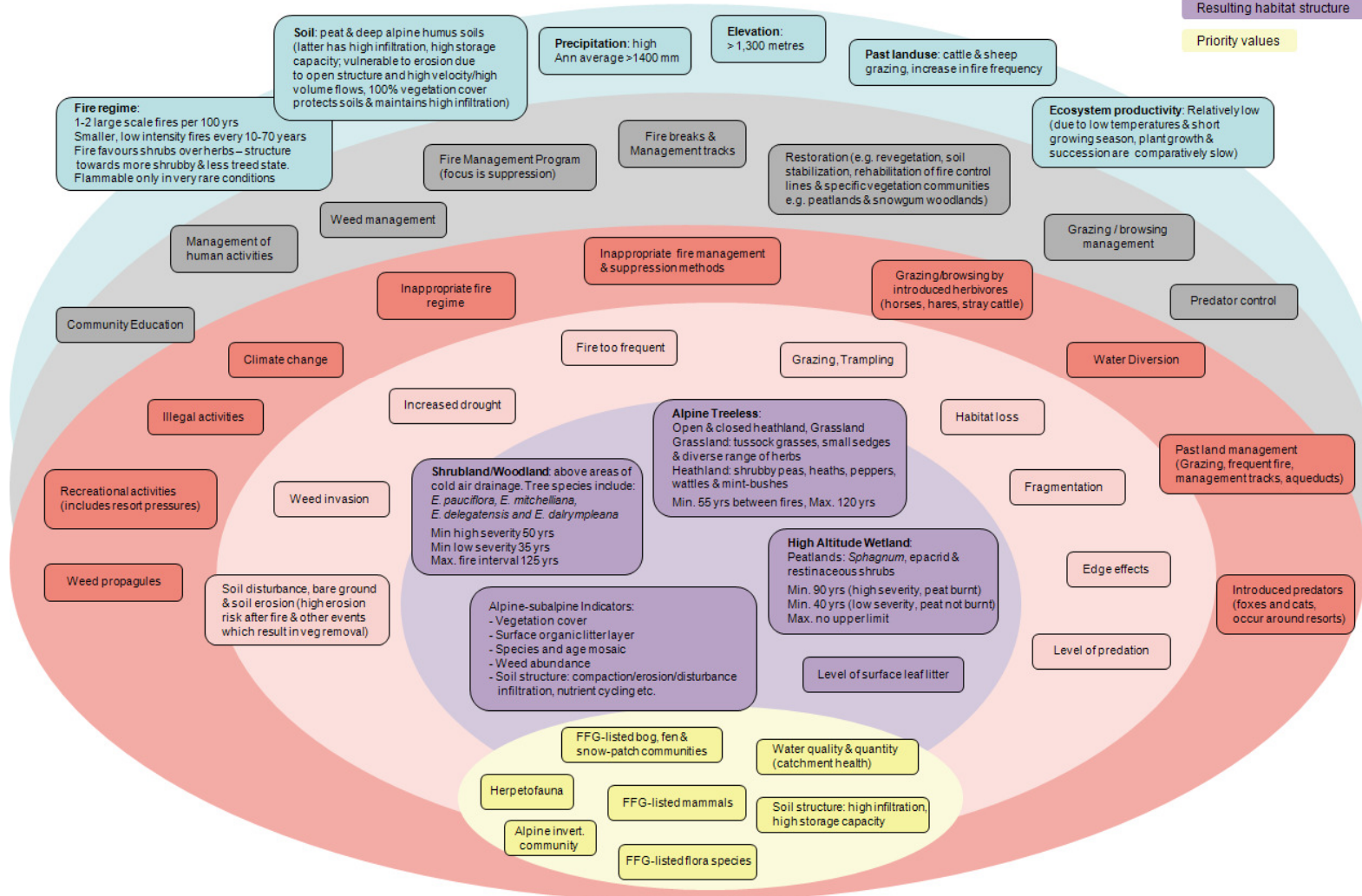
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Alpine

Alpine & subalpine Concept Map

(EVD14 High Altitude Shrubland/Woodland, EVD15 High Altitude Wetland, EVD16 Alpine Treeless)

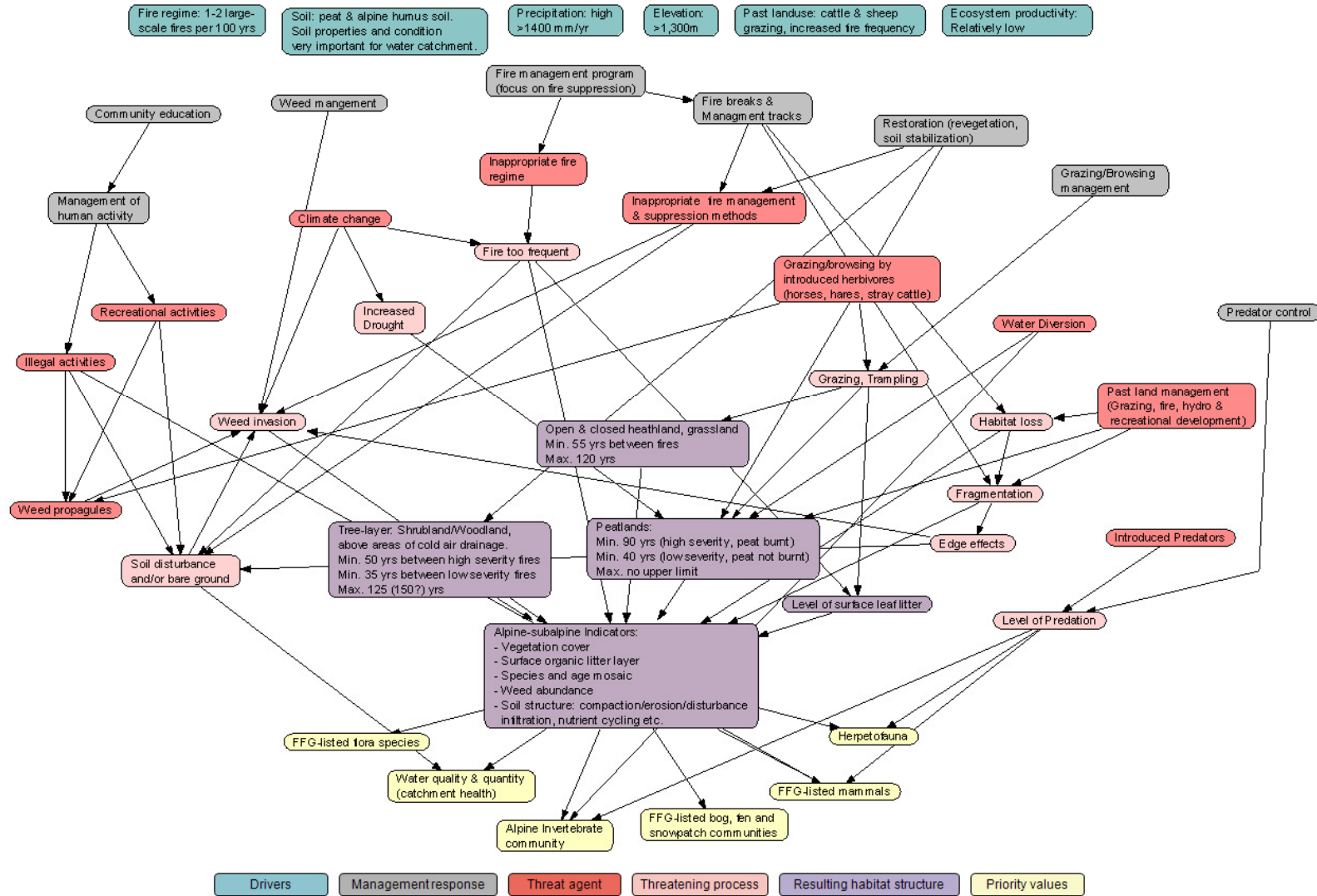
- Drivers
- Management response
- Threat agent
- Threatening process
- Resulting habitat structure
- Priority values



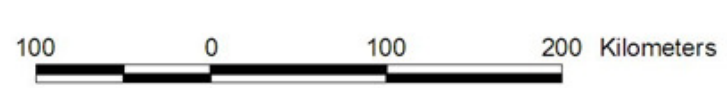
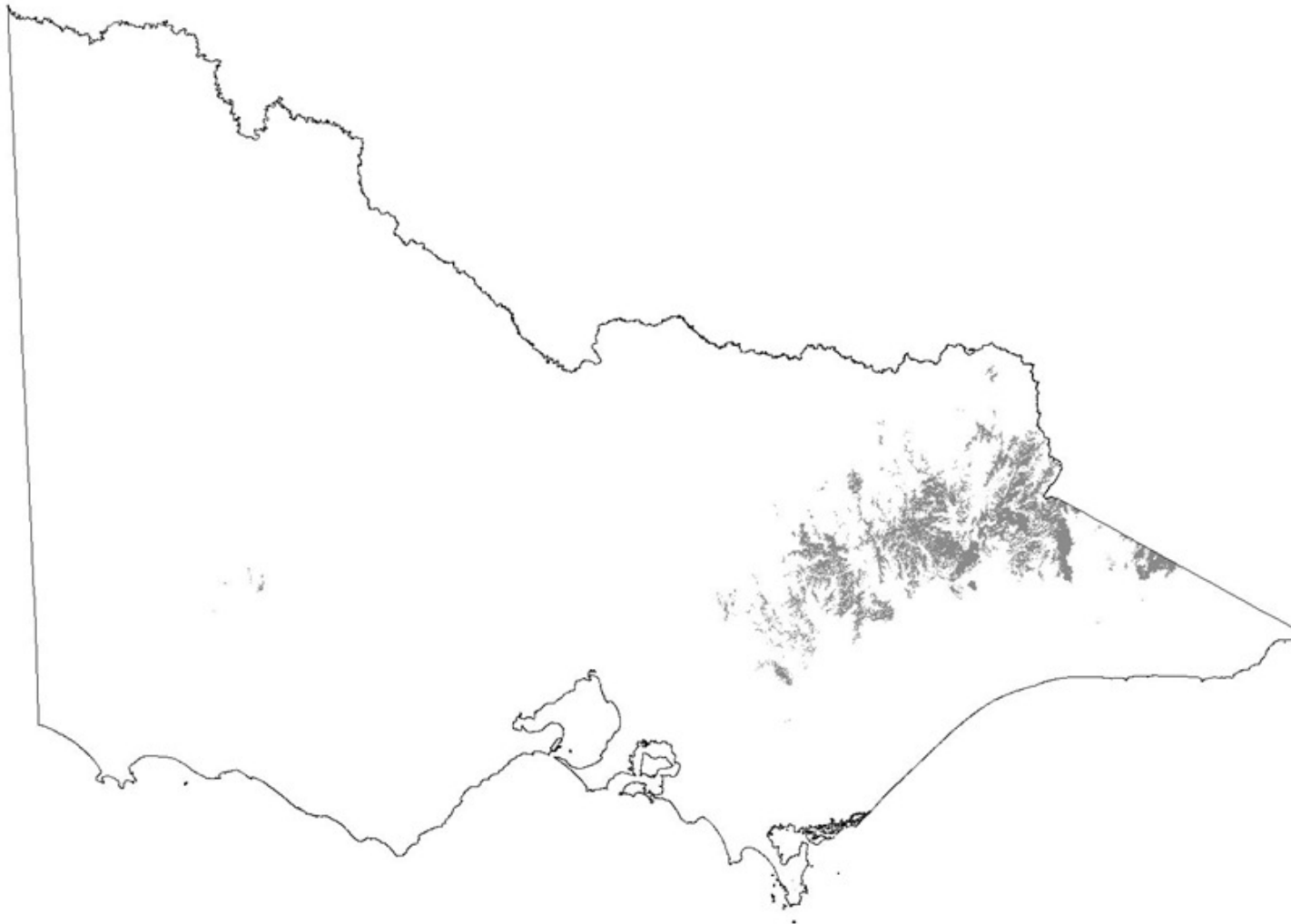
Alpine

Alpine & subalpine Causal Model

(EVD14 High Altitude Shrubland/Woodland, EVD15 High Altitude Wetland, EVD16 Alpine Treeless)



EVD 14 High Altitude Shrubland/Woodland



A129

EVD 15 High Altitude Wetland



A130

EVD 16 Alpine Treeless



A131

6.12. Inland Waters & Wetland – Riparian Forest (EVD11)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.12.1. Drivers

Fire regime: Minimum fire interval (for high severity as well as low severity fires) is 30 years; the maximum fire interval is 120 years (Cheal 2010). In the long-term absence of fire rainforest species will invade and may begin to dominate. Vegetation of this ecosystem type is only flammable in summer on high fire danger days.

Inundation regime: Riparian forest occurs in the zone adjacent to the river channel, and as a consequence has a continuously high water table.

Soil: Riparian forest typically has fertile well-developed soils with a deep litter; may be boggy in winter.

Rainfall: Occur in regions with relatively high rainfall.

Past landuse: Modification for past uses has included the removal of vegetation for stock access, irrigation, industry, urban development and drainage control.

Ecosystem productivity: Ecosystem productivity is high, with large, fast growing trees and abundant coarse woody debris.

6.12.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native), and water. Common weed species in this ecosystem type include Blackberry (*Rubus fruticosus* spp. agg.), Cat's Ear (*Hypochoeris radicata*), Self-heal (*Prunella vulgaris*), Thistle species (e.g. Common Sow-thistle, Spear Thistle), Sweet Briar (*Rosa rubiginosa*), Yorkshire Fog (*Holcus lanatus*), Grey Sallow (*Salix cinerea*) and Cherry Plum (*Prunus cerasifera*).

Illegal activities: These include the theft of flora and fauna, littering, unauthorized firewood collection, and off-road driving, riding and hiking, which can damage and/or remove vegetation and cause soil compaction and erosion.

Recreational activities: These include the use of mountain bikes, motor bikes and cars (includes four-wheel driving in some areas), and horse riding, hiking and camping. They may also include boating and fishing.

Climate change: The most important impact of climate change on these systems is likely to be increased drought and increased fire danger. This ecosystem type is less prone to fire than drier forests and woodlands, however, increased temperatures and decreased rainfall (and river flows) may result in increased fire frequency.

Inappropriate fire regime: The interval between fires may be too long (>120 years) or too short (<30 years), leading to a change in the composition and structure of native vegetation, and the loss (or reduced abundance) of dependent fauna.

Introduced herbivores: Includes horses, deer and pigs. Through preferential grazing/browsing may result in changed community structure and composition; other impacts include degradation of water quality (nutrient enrichment, sediment input, microorganisms) and soil disturbance and erosion (sedimentation of the waterway).

Introduced fish species: Introduced fish species include Carp (*Cyprinus carpio*), Mosquito fish (*Gambusia holbrooki*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*). Introduced fish species impact on native fish species through predation and competition for food and habitat. In addition, Carp increase water turbidity and damage aquatic plants.

Inappropriate water regime: Water regimes have been greatly modified since European settlement, mainly to regulate the amount and timing of flows in streams and rivers, to suit the requirements of human use (e.g. for food production and consumption). Water flows in these systems tend to be less regulated compared to areas where the Riverine Woodland / Forest ecosystem type occur. This variable includes consideration of the timing of in-channel and overbank flows, flood volume (for overbank events), flood frequency, flood duration and the maximum time between flood events. It also includes the loss of drying events because of artificially perennial flows. An inappropriate water regime will result in changes to the composition and structure of native vegetation communities, the loss of habitat for dependent fauna, and reduced diversity and abundance of in-stream biota.

Barriers (levees, dams/weirs): Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). Longitudinal barriers obstruct fish movement (creating isolated populations, excluding individuals/populations from breeding and feeding habitat), and reduce the transportation of sediment, plant propagules and aquatic invertebrates. They also reduce flow velocities allowing sediment deposition in weir pools, destroying important habitat. Lateral barriers restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (flooding is an important source of nutrient input into the channel) (Overton et al. 2009).

De-snagging & channelization: De-snagging is the removal of fallen trees and branches from the river channel and was undertaken to improve the passage of boats. The impacts of de-snagging include increased flow velocity, bed degradation, channel enlargement and loss of fish and invertebrate habitat. A number of native fish species are dependent on snags for habitat to shelter from currents, and to feed and spawn. Snag dependent species include the Murray cod, Trout Cod and Golden Perch (Robson et al. 2008). Channelization of streams and rivers was undertaken to improve navigation and increase channel capacity, and also to

extract sand and gravel. Channelization reduces habitat diversity, particularly areas of slack water, cover and shelter, food sources and spawning areas.

Surrounding landuse: Landuse in the areas adjacent to riparian forest may include forestry, agriculture and urban development. Riparian forest and the adjacent waterway are also vulnerable to the activities in the broader catchment area, such as the use of fertilizers, pesticides and herbicides; and the generation of sediment (a result of land clearing), litter, pollutants and sewage effluent.

Past clearing: Clearing and disturbance of riparian forest is widespread. Vegetation has been removed for stock access, irrigation, industry, urban development and drainage control. Catchment clearing has also resulted in the modification and degradation of riparian forest and associated waterways.

Introduced predators: Includes foxes, cats and wild dogs.

6.12.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions (e.g. bare ground, nutrient levels), and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Soil condition is particularly important in riparian forest as it has a direct relationship to water and habitat quality in the adjacent waterway. Soil disturbance and increased erosion in riparian forest contributes to the sedimentation and smothering of stream beds and biota (reducing hydraulic diversity), and increases turbidity and degrades water quality. Bare ground also provides the opportunity for the invasion and establishment of weed species.

Reduced water availability: This may result from extraction of water for human use (see Inappropriate Water Regime), and increased drought from climate change (see below).

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought are a decrease in flowering and nectar flow (particularly in eucalypts); a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire severity and

frequency. Increased drought will decrease water supply to waterways and wetland systems, and the surrounding vegetation communities.

Fire too frequent (interval too short): Fire interval less than 30 years, leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna. May also increase soil degradation and erosion, and reduce some important habitat components (e.g. tree hollows and woody debris).

Fire not frequent enough (interval too long): Fire interval greater than 120 years, leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna. In the long-term absence of fire rainforest species will invade and may begin to dominate.

Overgrazing: Horses, deer and pigs are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground). Erosion caused by introduced herbivores is an issue in this ecosystem type, as the high water content of the soils make them vulnerable to mechanical damage, and also because the products of erosion are likely to end up in the adjacent waterway.

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. In this ecosystem type causes includes insect attack (e.g. Psyllids), which may be accompanied by a decrease in insectivorous birds, changes to microclimate caused by edge effects, soil compaction, nutrient enrichment, disease (e.g. Phytophthora) and/or altered hydrology. Stressed trees generally are more susceptible to the effects of dieback.

Nutrient enrichment: Increased nutrient delivery to waterways (particularly nitrogen and phosphorus) may result in eutrophication, and an increase the growth of algae ('algal blooms'). Algal blooms have amenity and health impacts, but also reduce dissolved oxygen, and may result in the death of fish and other aquatic biota. Nutrient enrichment also has impacts on terrestrial and aquatic flora and fauna, and contributes to poor tree condition and the incidence of dieback.

Sedimentation: Soil erosion caused by land clearing, agriculture and forestry leads to an increase in suspended solids and turbidity in rivers and streams. When these settle the substrate of the waterway is modified by sedimentation, smothering habitat and biota. There may be a large pulse of sediment after major disturbances such as fire (or other events that denude large areas of vegetation).

Reduced connectivity: Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). Barriers have the effect of reducing connectivity, and creating isolated habitats so that aquatic organisms (e.g. fish and invertebrates) are excluded from breeding and feeding habitat. They also reduce the transportation of nutrients, plant propagules and sediment up and down the waterway, and restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (Overton et al. 2009). Connectivity may also be affected by water availability, as flows may be decreased to the point where only the deeper river and stream channels retain water (may be due to drought, or from water extraction).

Channel modification: River and stream channels can be modified in many different ways, and may include de-snagging, dredging, straightening and/or damming. Channel modification has been undertaken in the past to improve navigation and increase channel capacity, improve drainage, and to facilitate water extraction and storage, and water transport for irrigation and other uses. The effects of channel modification include reduced connectivity and loss of habitat.

Increased water temperature: The reduction in fringing vegetation (i.e. riparian forest) has the effect of increasing water temperature, which has effects on aquatic flora and fauna, and may be a factor in the increased occurrence of algal blooms. Warming trends that are occurring with climate change are also likely to increase water temperature.

Habitat loss: Past land management has resulted in the loss and fragmentation of this ecosystem type. Riparian forest was cleared for stock access, irrigation, industry, urban development and drainage control. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Edge effects: Higher edge-to-area ratio may result in increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance. Riparian forest typically occurs in linear strips along waterways, and edge effects may occur in response to roads and walking tracks, tourist facilities, and land clearance on adjacent land. Biota at or near the edge of an area of remnant vegetation may be affected by changes in the microclimate (e.g. fluxes of wind, radiation and water) which influence humidity and soil moisture. This can contribute to dieback and subsequent stand thinning.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that

introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.12.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion. Weed management in this ecosystem type must also consider the erosion which may accompany weed (especially tree) removal and the impact of herbicides transported by the waterway.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Grazing management: Grazing management in this ecosystem type will target introduced herbivores (e.g. deer, horses and pigs). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora).

Environmental water delivery: Environmental water delivery may be necessary to maintain the health of riparian forest and the associated waterway. The deviation from the natural flow regime is used to estimate 'flow stress' (includes consideration of volume of flows, timing, frequency and the maximum time between flows). The allocation of water for these systems would usually involve ensuring that enough water is left in the system to maintain the composition and structure of native vegetation communities that form this ecosystem type.

Restoration: Different restoration methods applied to the different ecosystem types. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. The habitat that occurs along waterways form important corridors for flora and fauna species, they facilitate movement and dispersion, and improve connectivity in the landscape; revegetation is therefore very important in this ecosystem type.

Ex-situ catchment management: Riparian forest within parks is affected by the activities that occur in the wider catchment area. These areas are managed by a variety of bodies that are guided by natural resource and catchment planning frameworks, which aim to address catchment-wide issues. Among these are programs to improve water quality, decrease sediment and nutrient delivery to waterways and wetlands and reduce flood peaks. It also includes the management of catchments to reduce the risk of lakes, wetlands and waterways from becoming salt-affected (e.g. salt interception schemes, improved land management to control salinity and waterlogging).

Control of introduced fish: Introduced fish species are very difficult to eradicate once they have established a breeding population. Control measures include electro-shocking and the use of poisons in areas of high infestation. Recreating natural habitats (e.g. revegetation of streamside, reinstating natural flow regimes) may be an effective longer term strategy, but will also require ongoing monitoring and control measures to keep introduced species in check. Examples of programs to manage carp include the use of poisons and commercial exploitation; biological control methods have also been proposed (using a virus specific to Carp).

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.12.5. Resultant Habitat Structure

Tree layer: Typical species include Manna Gum (*Eucalyptus viminalis*), Narrow-leafed Peppermint (*E. radiata*), Mountain Grey-gum (*E. cypellocarpa*) and River Peppermint (*E. elata*). These species occur in narrow strips along sheltered river banks, often less than 10m from the river edge.

Understorey: Some trees (e.g. *Acacia melanoxylon*), also climbers, tall dense shrubs, ferns, scrambling grasses and soft-leafed herbs. Sedges, rushes and wetland herbs occur at the river's edge.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced and the rate at which it is lost from the system (e.g. from fire). Ecosystem productivity riparian forest is high and coarse woody debris is usually abundant.

6.12.6. References

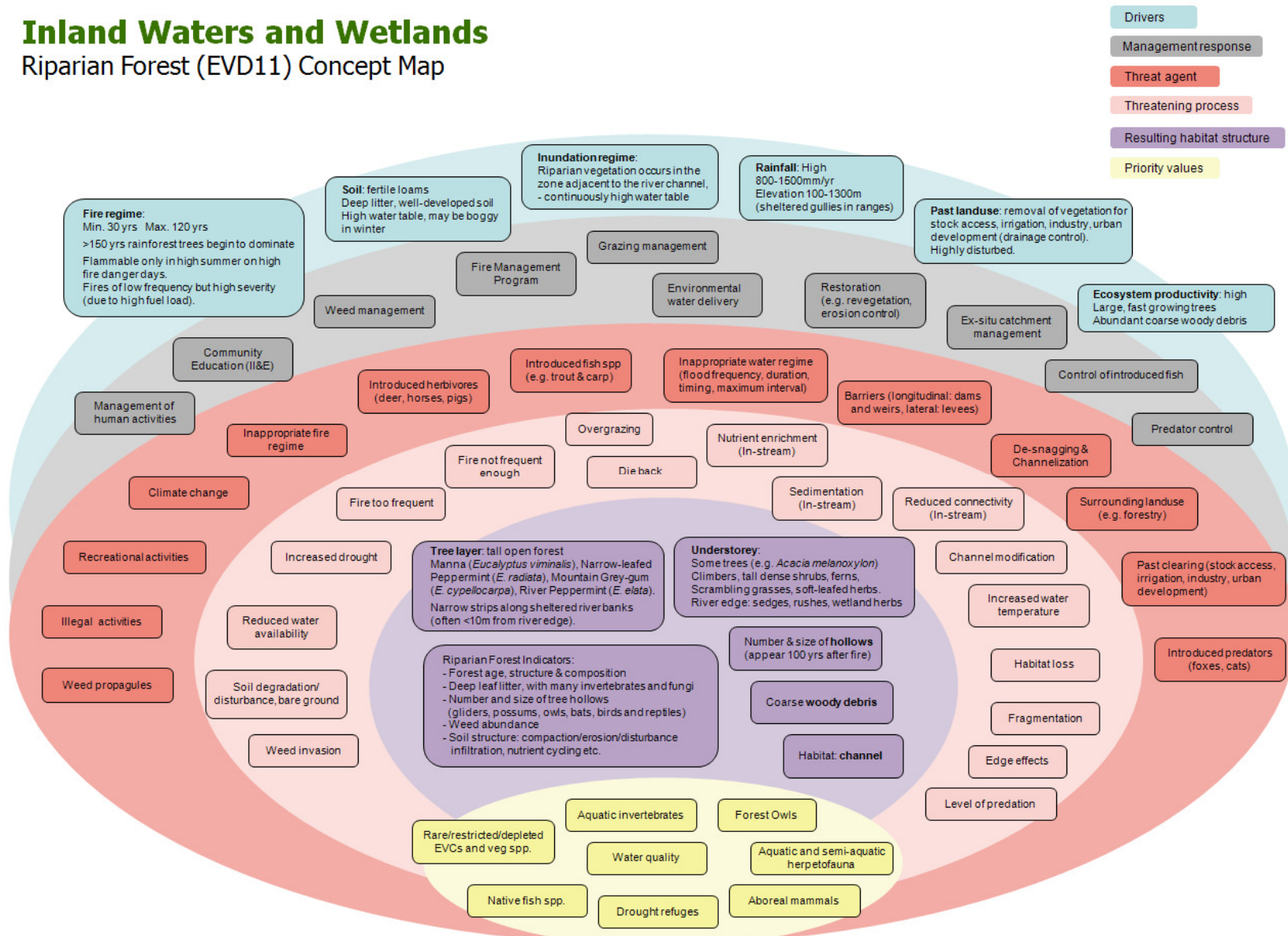
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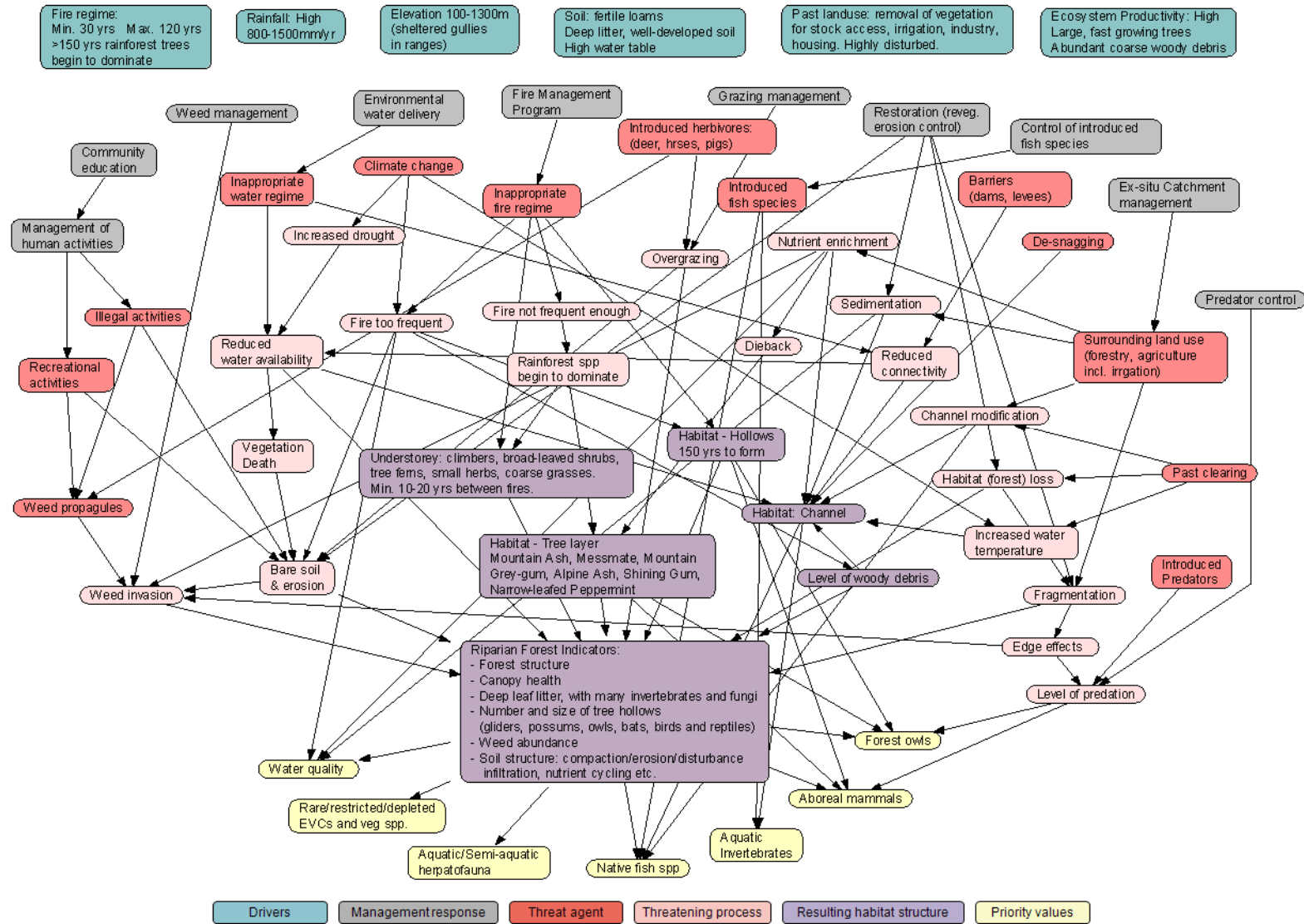
Inland Waters and Wetlands

Riparian Forest (EVD11) Concept Map



Inland Waters and Wetlands

Riparian Forest (EVD11) Causal Model



EVD 11 Riparian (higher rainfall)



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6.13. Inland Waters & Wetland – Riverine Forest & Woodland (EVD26)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.13.1. Drivers

Fire regime: The minimum fire interval for low severity fires is 10 years, for high severity fires it is 30 years. There is no upper limit for the fire interval, as few species are geared to regenerate post-fire, and flooding is the main regeneration event (Cheal 2010). This ecosystem type is flammable only occasionally, and fires tend to be low severity and patchy.

Inundation regime: Includes consideration of the timing of flows, and flood volume, frequency, duration and the maximum time between flood events to maintain ecological values. This ecosystem type is subject to periodic flooding, the desired interval between floods varies between 5-10 years.

Soil: Alluvial loams and clays.

Past landuse: This ecosystem type has been extensively cleared and/or modified for agriculture and urban development, where the tree layer may still occur, the native understory largely cleared or modified.

Ecosystem productivity: Moderate.

6.13.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native), and water. Common weed species in this ecosystem type include Soft Brome (*Bromus hordaceus* spp. *hordaceus*) and Red Brome (*Bromus rubens*), fescues, wild turnip, thistles (e.g. *Sonchus oleraceus*, *Cirsium vulgare*), horehound, Cat's ear (*Hypochoeris radicata*) and Grey Sallow (*Salix cinerea*).

Illegal activities: These include the theft of flora and fauna, littering, unauthorized firewood collection, and off-road driving, riding and hiking, which can damage and/or remove vegetation and cause soil compaction and erosion.

Recreational activities: These include the use of mountain bikes, motor bikes and cars (includes four-wheel driving in some areas), and horse riding, hiking and camping. They may also include boating and fishing.

Climate change: The most important impact of climate change on these systems is likely to be increased drought and increased fire danger. Increased temperatures and decreased rainfall (and river flows) may result in increased fire frequency.

Inappropriate fire regime: The interval between fires may be too short (<30 years), leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna.

Introduced herbivores: Includes rabbits, goats, pigs, horses and possibly cattle. Through preferential grazing and/or browsing may result in changed community structure and composition; other impacts include degradation of water quality (nutrient enrichment, sediment input, microorganisms) and soil disturbance and erosion (sedimentation of the waterway).

Overabundant native herbivores: Kangaroos may become overabundant in this ecosystem type.

Inappropriate water regime: This water in this ecosystem type tends to be highly regulated. Water regimes have been greatly modified since European settlement, mainly to regulate the amount and timing of flows in streams and rivers, to suit the requirements of human use (e.g. for food production, consumption). The water regime includes consideration of the timing of in-channel and overbank flows, flood volume (for overbank events), flood frequency, flood duration and the maximum time between flood events. It also includes the loss of drying events because of artificially perennial flows. An inappropriate water regime will result in changes to the composition and structure of native vegetation communities, the loss of habitat for dependent fauna, and reduced diversity and abundance of in-stream biota. The increase in Giant Rush (*Juncus ingens*) relative to the Common Reed (*Phragmites australis*) and Cumbungi (*Typha orientalis*), is thought to be due to altered flooding regimes (mainly that the peak flow is occurring in summer instead of winter).

Barriers (levees, dams/weirs): Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). Longitudinal barriers obstruct fish movement (creating isolated populations, excluding individuals/populations from breeding and feeding habitat), and reduce the transportation of sediment, plant propagules and aquatic invertebrates. They also reduce flow velocities allowing sediment deposition in weir pools, destroying important habitat. Lateral barriers restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (flooding is an important source of nutrient input into the channel) (Overton et al. 2009).

De-snagging & channelization: De-snagging is the removal of fallen trees and branches from the river channel and was undertaken to improve the passage of boats. The impacts of de-snagging include increased flow velocity, bed degradation, channel enlargement and loss of fish and invertebrate habitat. A number of native

fish species are dependent on snags for habitat to shelter from currents, and to feed and spawn. Snag dependent species include the Murray cod, Trout Cod and Golden Perch (Robson et al. 2008). Channelization of streams and rivers was undertaken to improve navigation and increase channel capacity, and also to extract sand and gravel. Channelization reduces habitat diversity, particularly areas of slack water, cover and shelter, food sources and spawning areas.

Introduced fish species: Introduced fish species include Carp (*Cyprinus carpio*), Mosquito fish (*Gambusia holbrooki*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*). Introduced fish significantly impact on native fish through predation, and competition for food and habitat. In addition, Carp increase water turbidity and damage aquatic plants.

Surrounding landuse: Adjacent land use may include forestry, agriculture and urban development. Riverine woodland and forest, and the adjacent waterway, are also vulnerable to the activities in the broader catchment area, such as the use of fertilizers, pesticides and herbicides; and the generation of sediment (a result of land clearing), litter, pollutants and sewage effluent.

Past clearing: Clearing and disturbance in this ecosystem type is widespread. Vegetation has been removed for stock access, irrigation, industry, urban development and drainage control. Catchment clearing has also resulted in the modification and degradation of riverine woodland and forest and their associated waterways.

Firewood collection: Firewood collection is permitted in some parks. Firewood collection reduces available habitat for ground dwelling mammals, birds, reptiles and invertebrates.

Introduced predators: Includes foxes and cats.

6.13.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions (e.g. bare ground, nutrient levels), and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem, and increased soil disturbance and compaction, the

amount of bare ground and the rate of soil erosion. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Soil condition is particularly important in riverine forest and woodland as it has a direct relationship to water and habitat quality in the adjacent waterway. Soil disturbance and increased erosion in riverine forest and woodland contributes to the sedimentation and smothering of stream beds and biota (reducing hydraulic diversity), and increases turbidity and degrades water quality. Bare ground also provides the opportunity for the invasion and establishment of weed species.

Reduced water availability: This may result from extraction of water for human use (see Inappropriate Water Regime), and increased drought from climate change (see below).

Salinity: Increased salinity occurs when the water table rises, bringing with it salts that occur naturally in the soil profile. The water table has risen in irrigated areas and areas where native deep-rooted perennial species have been replaced with herbaceous crop and pasture species (reducing the amount of evapotranspiration). Salinity reduces the diversity of native plants and animals, changes the composition and structure of native vegetation communities and may lead to soil erosion, reduced water quality in streams and rivers, and loss of riparian and riverine vegetation. Increased salinity threatens the habitat of fish and aquatic invertebrates, which in turn provide a food source for waterbirds.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought are a decrease in flowering and nectar flow (particularly in eucalypts); a decrease in plant and animal recruitment; change in flora and fauna diversity; decreased canopy and understorey cover; change in litter production and decomposition rate; and increased fire severity and frequency. Increased drought will also decrease water supply to waterways and wetland systems.

Fire too frequent (interval too short): Fire interval less than 30 years, leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna. May also increase soil degradation and erosion, and reduce some important habitat components (e.g. tree hollows and woody debris).

Overgrazing: Rabbits, goats, pigs, horses and over-abundant kangaroos are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less

palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground). Erosion caused by herbivores is an issue in this ecosystem type, as the high water content of the soils make them vulnerable to mechanical damage, and also because the products of erosion are likely to end up in the adjacent waterway.

Dieback: Dieback is the premature and rapid decline and death of trees, and has a number of root causes which are likely to interact. In this ecosystem type causes includes insect attack (e.g. Psyllids), which may be accompanied by a decrease in insectivorous birds, changes to microclimate caused by edge effects, soil compaction, nutrient enrichment, salinity, disease (e.g. Phytophthora) and/or altered hydrology (can include waterlogging and drought). Stressed trees are generally more susceptible to the effects of dieback.

Overly dense regrowth stands: Tree density is very high in some areas due to past disturbance. In these areas there are very few large, old, hollow-bearing trees, which impacts on the availability of fauna habitat (hollows and woody debris).

Nutrient enrichment: Increased nutrient delivery to waterways (particularly nitrogen and phosphorus) may result in eutrophication, and an increase the growth of algae ('algal blooms').

Algal blooms: Algal blooms have amenity and health impacts, but also reduce dissolved oxygen, and may result in the death of fish and other aquatic biota. Nutrient enrichment also has impacts on terrestrial and aquatic flora and fauna, and contributes to poor tree condition and the incidence of dieback.

Sedimentation: Soil erosion caused by land clearing, agriculture and forestry leads to an increase in suspended solids and turbidity in rivers and streams. When these settle the substrate of the waterway is modified by sedimentation, smothering habitat and biota. There may be a large pulse of sediment after major disturbances such as fire (or other events that denude large areas of vegetation).

Reduced connectivity: Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). Barriers have the effect of reducing connectivity, and creating isolated habitats so that aquatic organisms (e.g. fish and invertebrates) are excluded from breeding and feeding habitat. They also reduce the transportation of nutrients, plant propagules and sediment up and down the waterway, and restrict the flow of floodwater, biota and

other materials onto the floodplain, and interrupt return flows to the channel (Overton et al. 2009). Connectivity may also be affected by water availability, as flows may be decreased to the point where only the deeper river and stream channels retain water (may be due to drought, or from water extraction).

Channel modification: River and stream channels can be modified in many different ways, and include de-snagging, dredging, straightening and damming. Channel modification has been undertaken in the past to improve navigation and increase channel capacity, improve drainage, and to facilitate water extraction and storage, and water transport for irrigation and other uses. The effects of channel modification include reduced connectivity and loss of habitat.

Increased water temperature: The reduction in fringing vegetation (i.e. riverine forest and woodland) has the effect of increasing water temperature, which has effects on aquatic flora and fauna, and may be a factor in the increased occurrence of algal blooms. Warming trends that are occurring with climate change are also likely to increase water temperature.

Habitat loss: Past land management has resulted in the loss and fragmentation of this ecosystem type. Riverine woodland and forest was cleared for stock access, irrigation, industry, urban development and drainage control. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions.

Loss of woody debris: Woody debris provides habitat and food sources for ground dwelling mammals, birds, reptiles and invertebrates. It is removed with fire and firewood collection.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.13.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion. Weed management in this ecosystem type must also consider the erosion which may accompany weed (especially tree) removal and the impact of herbicides transported by the waterway.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Grazing management: Grazing management in this ecosystem type will target kangaroos and introduced herbivores (rabbits, goats, pigs, horses and possibly cattle). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora). It may also include the control of access to the waterway.

Restoration: Different restoration methods are applied to the different ecosystem types. Revegetation is a common method for improving a degraded system, and generally aims to lessen the impacts of fragmentation, habitat loss, soil degradation and erosion. The habitat that occurs along waterways form important corridors for flora and fauna species, they facilitate movement and dispersion, and improve connectivity in the landscape; revegetation is therefore very important in this ecosystem type.

Ecological thinning: Ecological thinning is the process of removing some smaller trees and allowing remaining dominant trees to grow faster and ultimately larger. Older, larger trees have hollows and other features which provide crucial habitat for many native invertebrate, bird and mammal species.

Environmental water delivery: Environmental water delivery is necessary to maintain the health of riverine forest and woodland, and the associated waterway. The deviation from the natural flow regime is used to estimate 'flow stress' (includes consideration of volume of flows, timing, frequency and the maximum time between flows) and determine the appropriate water regime to maintain the composition and structure of native vegetation communities that form this ecosystem type.

Ex-situ catchment management: Riverine forest and woodland within parks is affected by the activities that occur in the wider catchment area. These areas are managed by a variety of bodies that are guided by natural resource and catchment planning frameworks, which aim to address catchment-wide issues. Among these are programs to improve water quality, decrease sediment and nutrient delivery to waterways and wetlands and reduce flood peaks. It also includes the management of catchments to reduce the risk of lakes, wetlands and waterways from becoming salt-affected (e.g. salt interception schemes, improved land management to control salinity and waterlogging).

Control of introduced fish: Introduced fish species are very difficult to eradicate once they have established a breeding population. Control measures include electro-shocking and the use of poisons in areas of high infestation. Recreating natural habitats (e.g. revegetation of streamside, reinstating natural flow regimes) may be an effective longer term strategy, but will also require ongoing monitoring and control measures to keep introduced species in check. Examples of programs to manage carp include the use of poisons and commercial exploitation; biological control methods have also been proposed (using a virus specific to Carp).

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.13.5. Resultant Habitat Structure

Tree layer: Open forest to woodland, associated with drainage lines that may flood for extended periods. Most common tree species is River Red-gum (*E.*

camaldulensis), co-dominants depend on location: in the north-west the most common tree species is Black Box (*E. largiflorens*), in the Wimmera and north-central it is mostly Grey Box (*E. microcarpa*), and in the west and some central regions it is most commonly Yellow Box (*E. melliodora*).

Understorey: Open structure, species composition highly variable, depending on water depth and time since flooding. Usually includes shrubs or summer-growing grasses and herbs, common wattle species include *Acacia dealbata*, *A. salicina* and *A. stenophylla*. In north-west Victoria the understorey is made up of chenopods and other succulents. In southern regions the understorey is made up of grass species (*Themeda triandra*, *Austrostipa*, *Austrodanthonia* and *Poa*), sedges, rushes and shrubs.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire)

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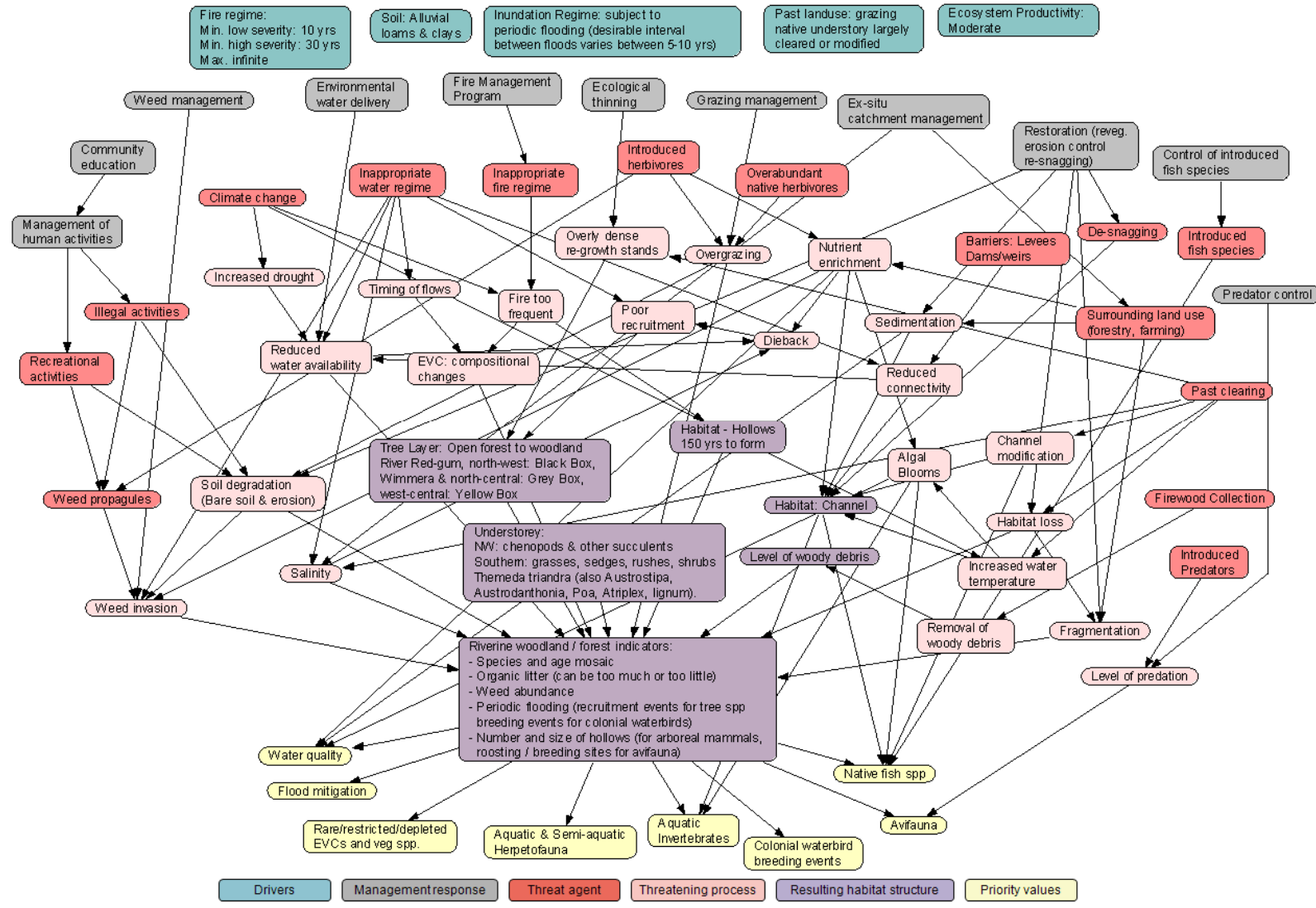
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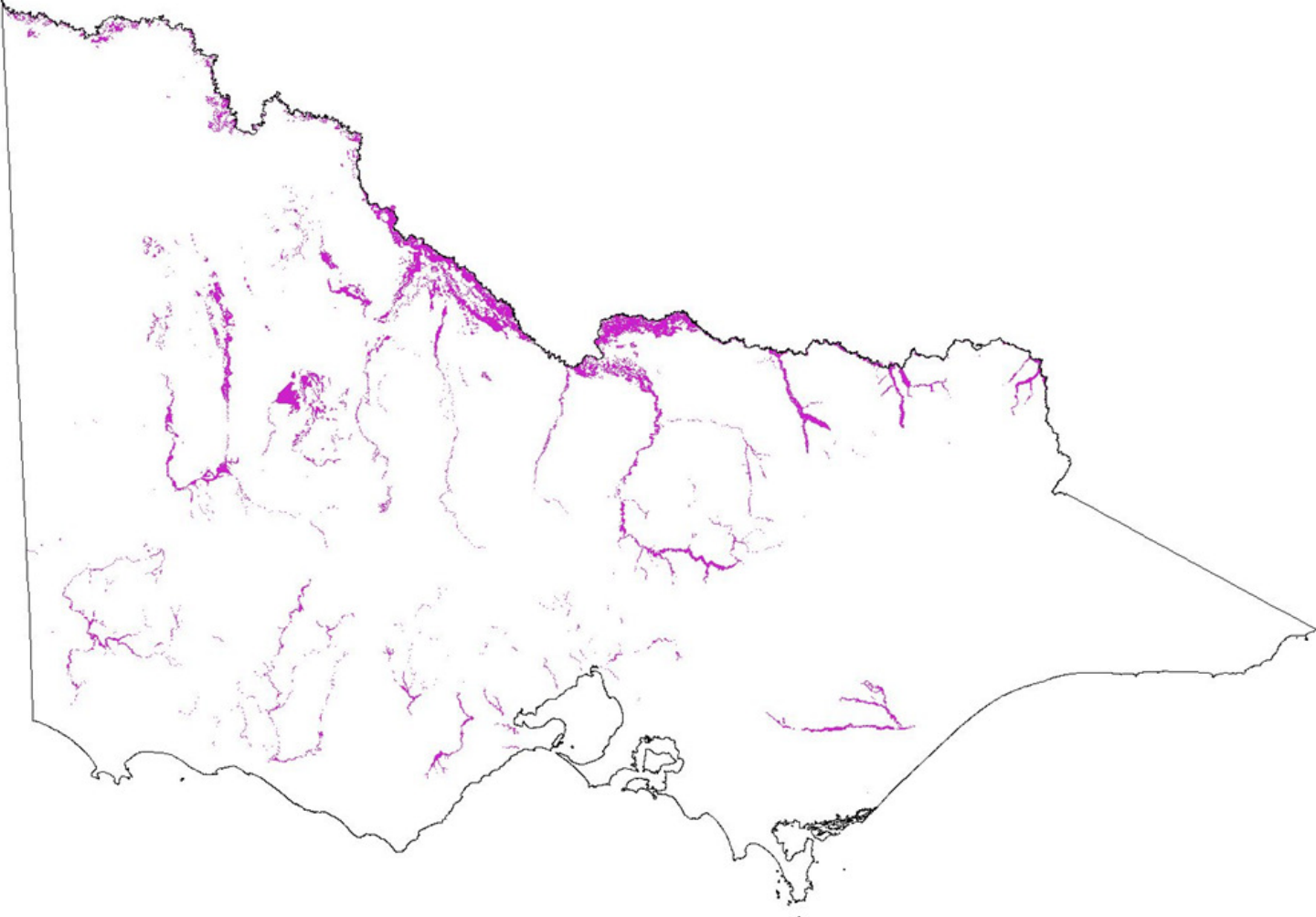
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Inland Waters and Wetlands

Riverine Woodland / Forest (EVD25) Causal Model



EVD 25 Riverine Woodland / Forest



100 0 100 200 Kilometers



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6.14. Inland Waters & Wetland – Permanent Freshwater Wetland (EVD5)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.14.1. Drivers

Fire regime: The minimum fire interval for low severity fires is 8 years; there is no upper limit for the fire interval, as few species are geared to regenerate post-fire (Cheal 2010). This ecosystem type is largely non-flammable, as the fuel is usually too discontinuous to support fire. May burn in exceptional conditions (e.g. after protracted drought). Regeneration in this ecosystem type is primarily dependent on water supply (rainfall, flooding and/or groundwater).

Soil: Variable, often relatively fertile with significant organic content.

Inundation regime: Includes consideration of the timing of flows, and flood volume, frequency, duration and the maximum time between flood events to maintain ecological values. The vegetation of this ecosystem type is typically dependent on flooding around every 5 years.

Past landuse: This ecosystem type has been extensively cleared and/or modified for agricultural and urban development, including draining to create reclaimed land.

6.14.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native), and water. Weed species in this ecosystem type include Aster-weed (*Aster subulatus*), Water Buttons (*Cotula coronopifolia*), aquatic weeds may include Alligator Weed, several Arrowhead species, Cabomba, Dense Waterweed, Egeria, Giant Water Lily and Water Hyacinth.

Illegal activities: These include the theft of flora and fauna, littering, unauthorized firewood collection, and off-road driving, riding and hiking, which can damage and/or remove vegetation and cause soil compaction and erosion.

Recreational activities: These include the use of mountain bikes, motor bikes and cars (includes four-wheel driving in some areas), and horse riding, hiking and camping. They may also include boating and fishing.

Climate change: The most important impact of climate change on these systems is likely to be increased drought, and possibly also increased fire danger.

Inappropriate fire regime: The interval between fires may be too short (<8 years), leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna.

Inappropriate water regime: This ecosystem type tends to be a component of highly regulated systems. The water regime includes consideration of the timing of flows, flood

volume, flood frequency, flood duration and the maximum time between flood events, and the maintenance of water levels between floods. An inappropriate water regime will result in changes to the composition and structure of native vegetation communities, the loss of habitat for dependent fauna, and reduced diversity and abundance of in-stream biota. The increase in the native *Juncus ingens* relative to the Common Reed (*Phragmites australis*) and Cumbungi (*Typha orientalis*), is probably due to altered flooding regimes (peak flows occurring in summer instead of winter).

Introduced herbivores: Includes rabbits, goats and pigs. Through preferential grazing and/or browsing introduced herbivores may change community structure and composition; other impacts include degradation of water quality (nutrient enrichment, harmful microorganisms) and soil disturbance and erosion (sedimentation of the wetland).

Barriers (levees, dams/weirs): Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). Longitudinal barriers obstruct fish movement (creating isolated populations, excluding individuals/populations from breeding and feeding habitat), and reduce the transportation of sediment, plant propagules and aquatic invertebrates. They also reduce flow velocities allowing sediment deposition in weir pools, destroying important habitat. Lateral barriers restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (flooding is an important source of nutrient input into the channel) (Overton et al. 2009).

Introduced fish species: Introduced fish species include Carp (*Cyprinus carpio*), Mosquito fish (*Gambusia holbrooki*), Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*). Introduced fish significantly impact on native fish through predation, and competition for food and habitat. In addition, Carp increase water turbidity and damage aquatic plants.

Surrounding landuse: Adjacent land use may include forestry, agriculture and urban development. Wetlands are also vulnerable to the activities in the broader catchment area, such as the use of fertilizers, pesticides and herbicides; and the generation of sediment (a result of land clearing), litter, pollutants and sewage effluent, and increased salinity.

Past clearing: Clearing, draining and disturbance in this ecosystem type is widespread. Vegetation has been removed for stock access, irrigation, industry, urban development and drainage control. Catchment clearing has also resulted in the modification and degradation of wetlands.

Introduced predators: Includes foxes and cats.

6.14.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions (e.g. bare ground, nutrient levels), and whether there are weed management strategies in place.

Soil degradation/disturbance/bare ground: Past land use (including clearing) and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem type, and increased soil disturbance and compaction, the amount of bare ground and the rate of soil erosion. Soil disturbance and/or compaction may also result from recreational activities, illegal (especially off-track) activities, and fire. Erosion reduces soil water storage capacity and water quality, and compaction reduces infiltration and impedes root growth. Soil condition surrounding permanent wetlands is particularly important in as it has a direct relationship to water and habitat quality. Soil disturbance and increased erosion in this ecosystem type contributes to the sedimentation, increases turbidity and degrades water quality. Bare ground also provides the opportunity for the invasion and establishment of weed species.

Reduced water availability: This may result from extraction of water for human use (see Inappropriate Water Regime), and increased drought from climate change (see below). Water availability can also be reduced as a result of recruitment of trees adjacent to the wetland, which may cause open water in the wetland to contract.

Salinity: Increased salinity occurs when the water table rises, bringing with it salts that occur naturally in the soil profile. The water table has risen in irrigated areas and areas where native deep-rooted perennial species have been replaced with herbaceous crop and pasture species (reducing the amount of evapotranspiration). Salinity reduces the diversity of native plants and animals, changes the composition and structure of native vegetation communities and may lead to soil erosion, reduced water quality in streams and rivers, and loss of riparian and riverine vegetation. Increased salinity threatens the habitat of fish and aquatic invertebrates, which in turn provide a food source for waterbirds.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought a decrease in plant and animal recruitment; change in flora and fauna diversity; change in litter production and decomposition rate; and increased fire severity and frequency. Increased drought will decrease water supply to wetland systems.

Fire too frequent (interval too short): Fire interval less than 8 years, leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna. May also increase soil degradation and erosion, and reduce some important habitat components (e.g. tree hollows and woody debris).

Overgrazing: Rabbits, goats and pigs are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground). Erosion caused by herbivores is an issue in this ecosystem type, as the high water content of the soils make them vulnerable to mechanical damage, and also because the products of erosion are likely to end up in the adjacent wetland.

Nutrient enrichment: Increased nutrient delivery to wetlands (particularly nitrogen and phosphorus) may result in eutrophication, and an increase the growth of algae ('algal blooms').

Algal blooms: Algal blooms have amenity and health impacts, but also reduce dissolved oxygen, and may result in the death of fish and other aquatic biota. Nutrient enrichment also has impacts on terrestrial and aquatic flora and fauna, and contributes to poor tree condition and the incidence of dieback.

Reduced connectivity: Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). Barriers have the effect of reducing connectivity, and creating isolated habitats so that aquatic organisms (e.g. fish and invertebrates) are excluded from breeding and feeding habitat. They also reduce the transportation of nutrients, plant propagules and sediment up and down the waterway, and restrict the flow of floodwater, biota and other materials onto the floodplain, and interrupt return flows to the channel (Overton et al. 2009). Connectivity may also be affected by water availability, as flows may be decreased to the point where only the deeper river and stream channels retain water (may be due to drought, or from water extraction). Some permanent freshwater wetlands are now isolated from their water source (e.g. some River Murray Icon sites), and water may need to be pumped from the river channel to maintain these habitats.

Sedimentation: Soil erosion caused by land clearing, agriculture and forestry leads to increased sediment delivery to rivers and wetlands, smothering habitat and biota. There may be a large pulse of sediment after major disturbances such as fire (or other events that denude large areas of vegetation).

Habitat loss: Past land management has resulted in the loss and modification of this ecosystem type, which included draining for agriculture and urban development. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.14.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion. Weed management in this ecosystem type must also consider the erosion which may accompany weed (especially tree) removal and the impact of herbicides transported by water.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Environmental water delivery: Environmental water delivery may be necessary to maintain the health of many Permanent Freshwater Wetlands. This may include strategic water delivery to areas that relied on overbank flows, e.g. pumping from the river channel into wetlands, billabongs, lagoons, etc.

Grazing management: Grazing management in this ecosystem type will target introduced herbivores (rabbits, goats, pigs and possibly cattle). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora). It may also include the control of access to the waterway.

Ex-situ catchment management: Wetlands within parks are affected by the activities that occur in the wider catchment area. These areas are managed by a variety of bodies that are guided by natural resource and catchment planning frameworks, which aim to address catchment-wide issues. Among these are programs to improve water quality and decrease sediment and nutrient delivery to waterways and wetlands. It also includes the management of catchments to reduce the risk of lakes, wetlands and waterways from becoming salt-affected (e.g. salt interception schemes, improved land management to control salinity and waterlogging).

Restoration: Different restoration methods are applied to the different ecosystem types. Restoration in this ecosystem type is likely to include reinstatement of the natural water regime and vegetation structure and composition.

Control of introduced fish: Introduced fish species are very difficult to eradicate once they have established a breeding population, control measures include electro-shocking and the use of poisons in areas of high infestation. Recreating natural habitats (e.g. revegetation of streamside, reinstating natural flow rates) may be an effective longer term strategy, but will also require ongoing control measures to keep introduced species in check. Examples of programs to manage carp include the use of poisons and commercial exploitation; biological control methods have also been proposed (using a virus specific to Carp).

Predator control: The applicability of monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.14.5. Resultant Habitat Structure

Tree layer: usually absent, shrubs occur at margins and commonly include Prickly Tea-tree (*Leptospermum continentale*), Scented Paperbark (*Melaleuca squarrosa*) and Swamp Paperbark (*M. ericifolia*).

Aquatic /semi-aquatic plants: Common species include Water-milfoil (e.g. *Myriophyllum verrucosum*), sedges (e.g. *Carex apressa*), reeds (e.g. *Phragmites australis*), rushes (e.g. *Juncus ingens*) and Cumbungi (e.g. *Typha domingensis*).

6.14.6. References

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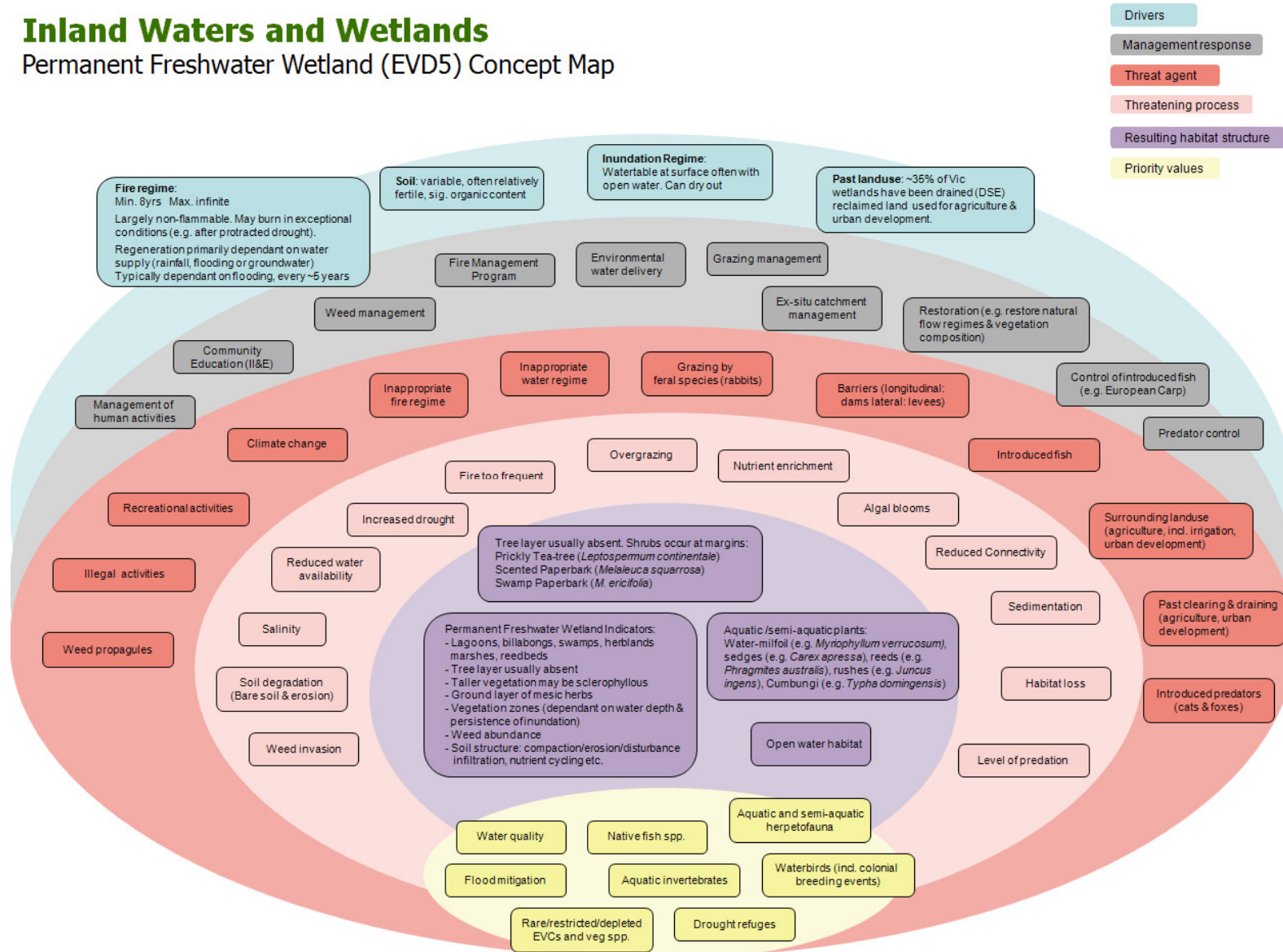
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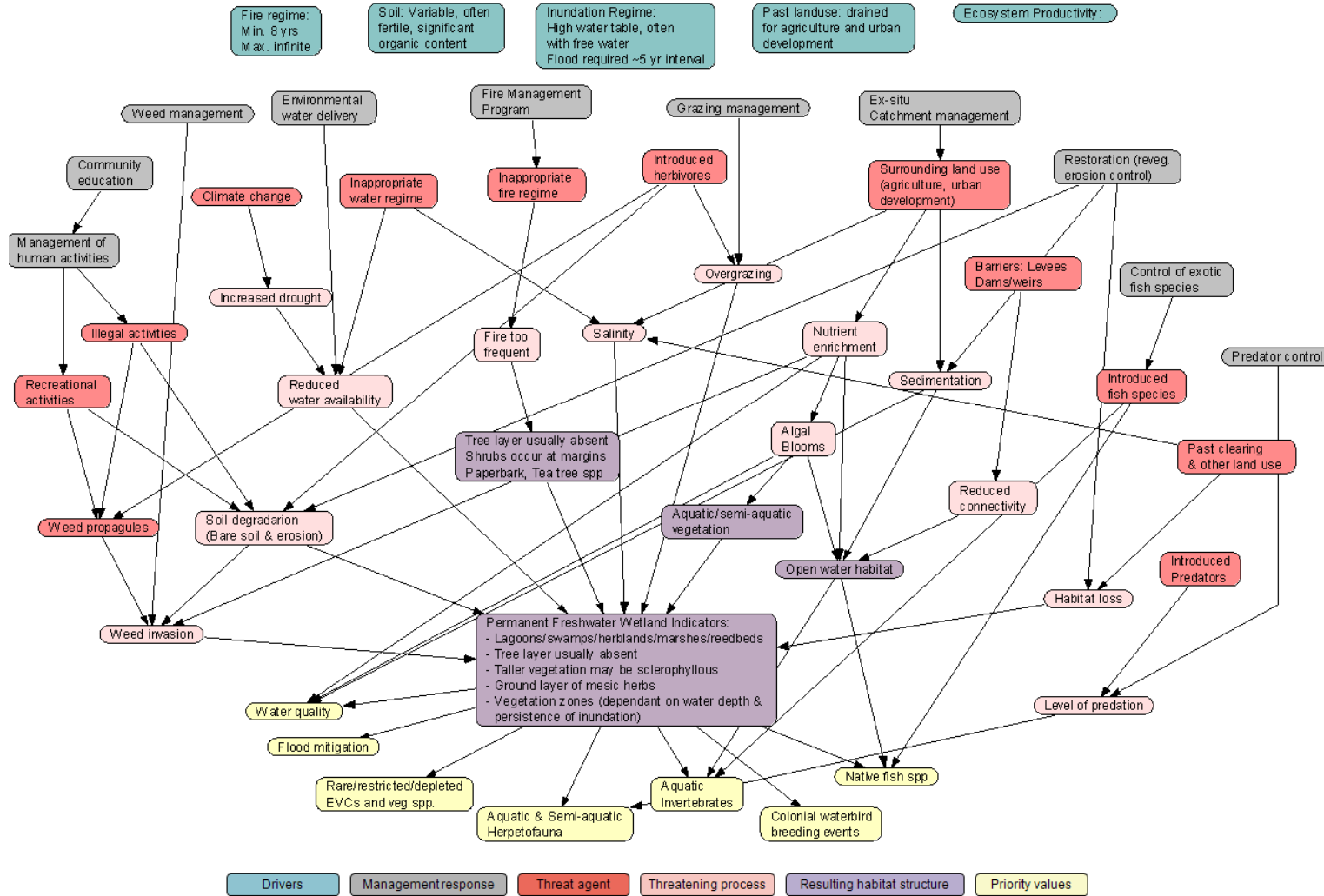
Inland Waters and Wetlands

Permanent Freshwater Wetland (EVD5) Concept Map

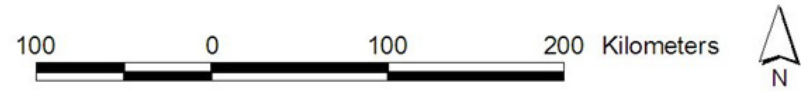
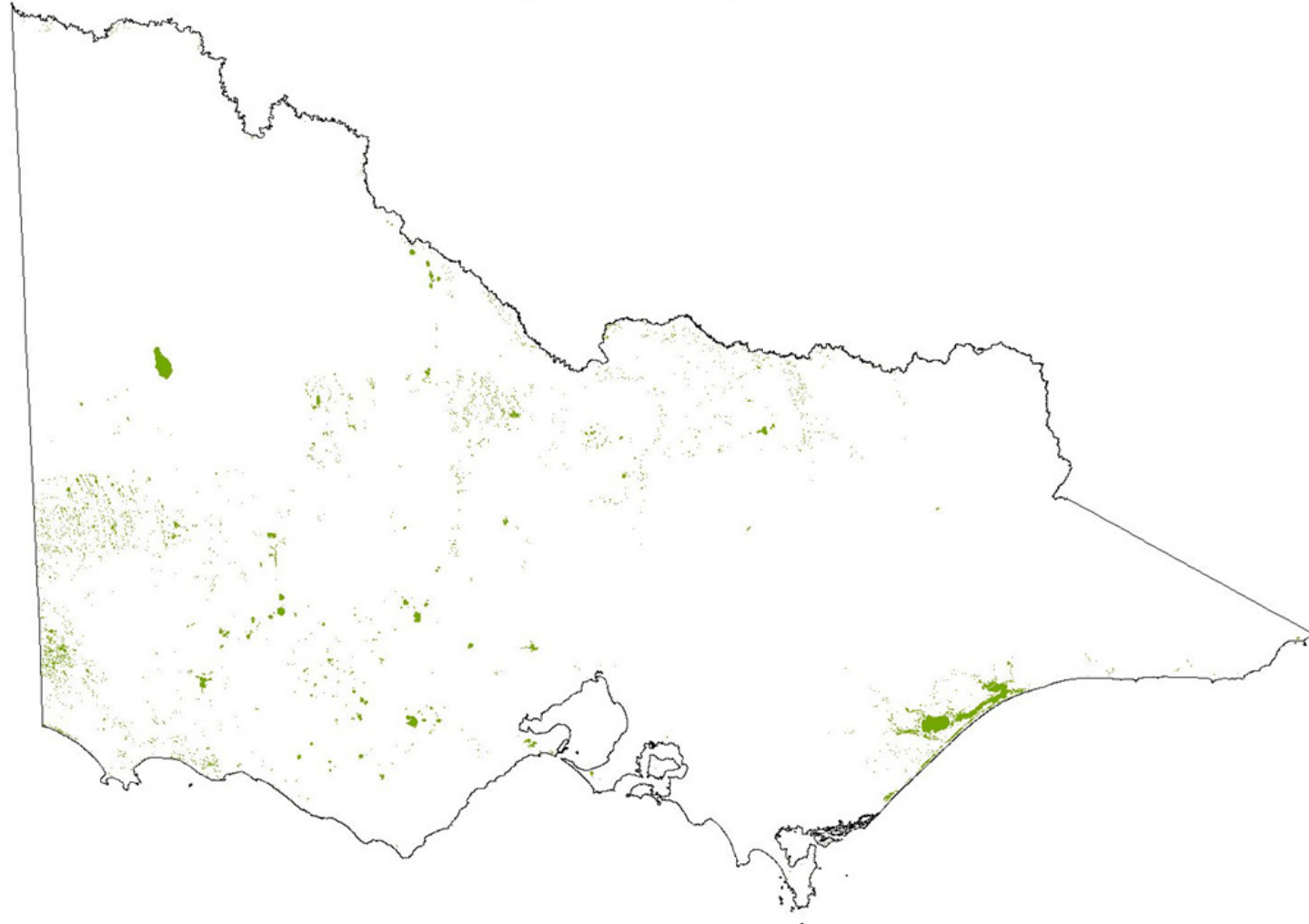


Inland Waters and Wetlands

Permanent Freshwater Wetland (EVD5) Causal Model



EVD 5 Freshwater Wetland (permanent)



A169

6.15. Inland Waters & Wetland – Ephemeral Freshwater Wetland (EVD26)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.15.1. Drivers

Fire regime: The minimum fire interval for low severity fires is 2 years; there is no upper limit for the fire interval, as few species are geared to regenerate post-fire (Cheal 2010). This ecosystem type is largely non-flammable, though it may burn at the margins. Regeneration in

this ecosystem type is primarily dependent on water supply (rainfall, flooding or groundwater).

Soil: Variable, often relatively fertile with, anoxic when inundated, deeply cracked and parched between inundations.

Inundation regime: Includes consideration of the timing, volume, frequency, duration and the maximum time between flood events to maintain ecological values. The vegetation of this ecosystem type subject to sporadic but extended inundation is typically dependent on flooding approximately every 5 to 10 years.

Past landuse: This ecosystem type has been extensively cleared and/or modified for agricultural and urban development, may be used for grazing (when in dry phase) and cropping (when in wet phase).

6.15.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native), and water. Weed species in this ecosystem type include Spear Thistle, Cat's Ear, Wild Oat, Squirrel-tail Fescue, Mediterranean Barley-grass, Lesser Quaking-grass and Cluster Clover.

Illegal activities: These include the theft of flora and fauna, littering and off-road driving, riding and hiking, which can damage and/or remove vegetation and cause soil compaction and erosion.

Recreational activities: These include the use of mountain bikes, motor bikes and cars, hiking and camping. They may also include boating and fishing.

Climate change: The most important impact of climate change on these systems is likely to be increased drought and the impact on inundation regimes, and possibly also increased fire danger.

Inappropriate fire regime: The interval between fires may be too short (<2 years), leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna.

Inappropriate water regime (wetting-drying cycle): The water regime includes consideration of the timing, volume, frequency, and duration of floods and the maximum time between flood events. An inappropriate water regime will result in changes to the composition and structure of native vegetation communities, and the loss of habitat for dependent fauna. Ephemeral freshwater wetlands tend to be very small, non-connected and patchy. They occur on flat plains in low points in the landscape. They rely on overland flow

and have specific wetting and drying cycles, which have been modified by extended drought conditions (the 'Drying lakes' phenomenon). This causes a number of problems, including an excess of dust, which may have pollutants in it, and which may cause an amenity problem. It also creates a habitat that is more suitable for fairy grass (*Lachnagrostis filiformis*), which increases the fire risk and also causes a loss of amenity (has been a nuisance in Lake Wendouree, Lake Learmonth and Lake Burumbeet). There is a particular succession that occurs in these systems after a flood as the area dries out; succession may be stalled if the wetting-drying cycle is interrupted and the system spends too much time in any one phase.

Introduced herbivores: Includes rabbits. Through preferential grazing and/or browsing introduced herbivores may change community structure and composition, inhibit regeneration and cause soil disturbance and erosion.

Barriers (levees, dams/weirs): Barriers to water movement may be longitudinal (e.g. dams and weirs) or lateral (e.g. levees and other floodplain developments). The wetting/drying cycle of Ephemeral Freshwater Wetlands may be affected by manipulations of the surrounding areas drainage and hydrology, e.g. if a gate is placed at the bottom of the drainage line this can keep the area too wet.

Surrounding landuse: Adjacent land use may include forestry, agriculture and urban development. Wetlands are also vulnerable to the activities in the broader catchment area, such as the use of fertilizers, pesticides and herbicides; and the generation of sediment (a result of land clearing), litter, pollutants and sewage effluent, and increased salinity.

Past clearing: This ecosystem type has been extensively cleared and/or modified for agricultural and urban development, may be used for grazing (when in dry phase) and cropping (when in wet phase). Catchment clearing has also resulted in the modification and degradation of these wetlands.

Introduced predators: Includes foxes and cats.

6.15.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions (e.g. bare ground, nutrient levels), and whether there are weed management strategies in place.

Increased erosion and movement of soils, degradation of biological soil crust: Past land use / land clearing and the introduction of herbivores (managed and feral) have reduced the cover of vegetation and biological soil crusts, and increased soil disturbance, the amount of bare ground and the rate of soil erosion. Erosion has impacts on soil water storage capacity and water quality. Bare ground provides the opportunity for the invasion and

establishment of weed plant species. Soil disturbance, erosion, and bare ground may also result from recreational activities, illegal activities (especially off-track activities) and fire.

Reduced water availability: This may result from extraction of water for human use (see Inappropriate Water Regime), and increased drought from climate change (see below).

Salinity: Increased salinity occurs when the water table rises, bringing with it salts that occur naturally in the soil profile. The water table has risen in irrigated areas and areas where native deep-rooted perennial species have been replaced with herbaceous crop and pasture species (reducing the amount of evapotranspiration). Salinity reduces the diversity of native plants and animals, changes the composition and structure of native vegetation communities and may lead to soil erosion, reduced water quality in streams and rivers, and loss of riparian and riverine vegetation. Increased salinity threatens the habitat of fish and aquatic invertebrates, which in turn provide a food source for waterbirds.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter droughts. Among the affects of drought a decrease in plant and animal recruitment; change in flora and fauna diversity; change in litter production and decomposition rate; and increased fire severity and frequency. Increased drought will decrease water supply to wetland systems.

Fire too frequent (interval too short): Fire interval less than 2 years, leading to a change in the composition and structure of native vegetation, and the loss of habitat for dependent fauna. May also increase the level of soil degradation and erosion.

Overgrazing: Rabbits are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance and creation of bare ground).

Nutrient enrichment: Increased nutrient delivery to wetlands (particularly nitrogen and phosphorus) may result in eutrophication, and an increase the growth of algae ('algal blooms'). These systems are fed by runoff, which collects the fertilizers from the surrounding catchment. If flows aren't large enough or frequent enough to allow regular flushing algal blooms may become a significant issue.

Algal blooms: Algal blooms have amenity and health impacts, but also reduce dissolved oxygen, and may result in the death of aquatic biota.

Reduced connectivity: Barriers to water movement may affect these systems by preventing runoff reaching the wetlands from the surrounding catchment.

Habitat loss: Past land management has resulted in the loss and modification of this ecosystem type. Modifications to hydrology (patterns of drainage) have diverted water from some Ephemeral Freshwater Wetlands, and caused others to be wet for long periods. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.15.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits. See main document for further details.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife. See main document for further details.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, using the Key Fire Response Species to set the minimum and maximum desirable fire intervals.

Grazing management: Grazing management in this ecosystem type will target introduced herbivores (mainly rabbits). The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition, population trends in threatened flora). It may also include the control of access to the wetland.

Environmental water delivery: Environmental water delivery may be necessary to maintain the health of these systems; however, to be feasible the system would need to be close to other assets, e.g. river channels.

Ex-situ catchment management: Wetlands within parks are affected by the activities that occur in the wider catchment area. These areas are managed by a variety of bodies that are guided by natural resource and catchment planning frameworks, which aim to address catchment-wide issues. Among these are programs to improve water quality and decrease sediment and nutrient delivery to waterways and wetlands. It also includes the management of catchments to reduce the risk of lakes, wetlands and waterways from becoming salt-affected (e.g. salt interception schemes, improved land management to control salinity and waterlogging).

Restoration: Different restoration methods are applied to the different ecosystem types. Restoration in this ecosystem type is likely to include reinstatement of the natural water regime and vegetation composition.

Predator control: The applicability of monitoring and predator control programs are guided by management and conservation objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species occur that are vulnerable to predation.

6.15.5. Resultant Habitat Structure

Tree layer: Occasional emergent trees, may include River Red-gum (*E. camaldulensis*), Yellow Box (*E. melliodora*) and Black Box (*E. largiflorens*) (from Riverine Woodland/Forest) or tea-tree / paperbark shrubs.

Understorey: Shrubs (e.g. Lignum (*Muehlenbeckia florulenta*), chenopods), herbs, grasses, and aquatic and semi-aquatic herbs, sedges and rushes.

6.15.6. References

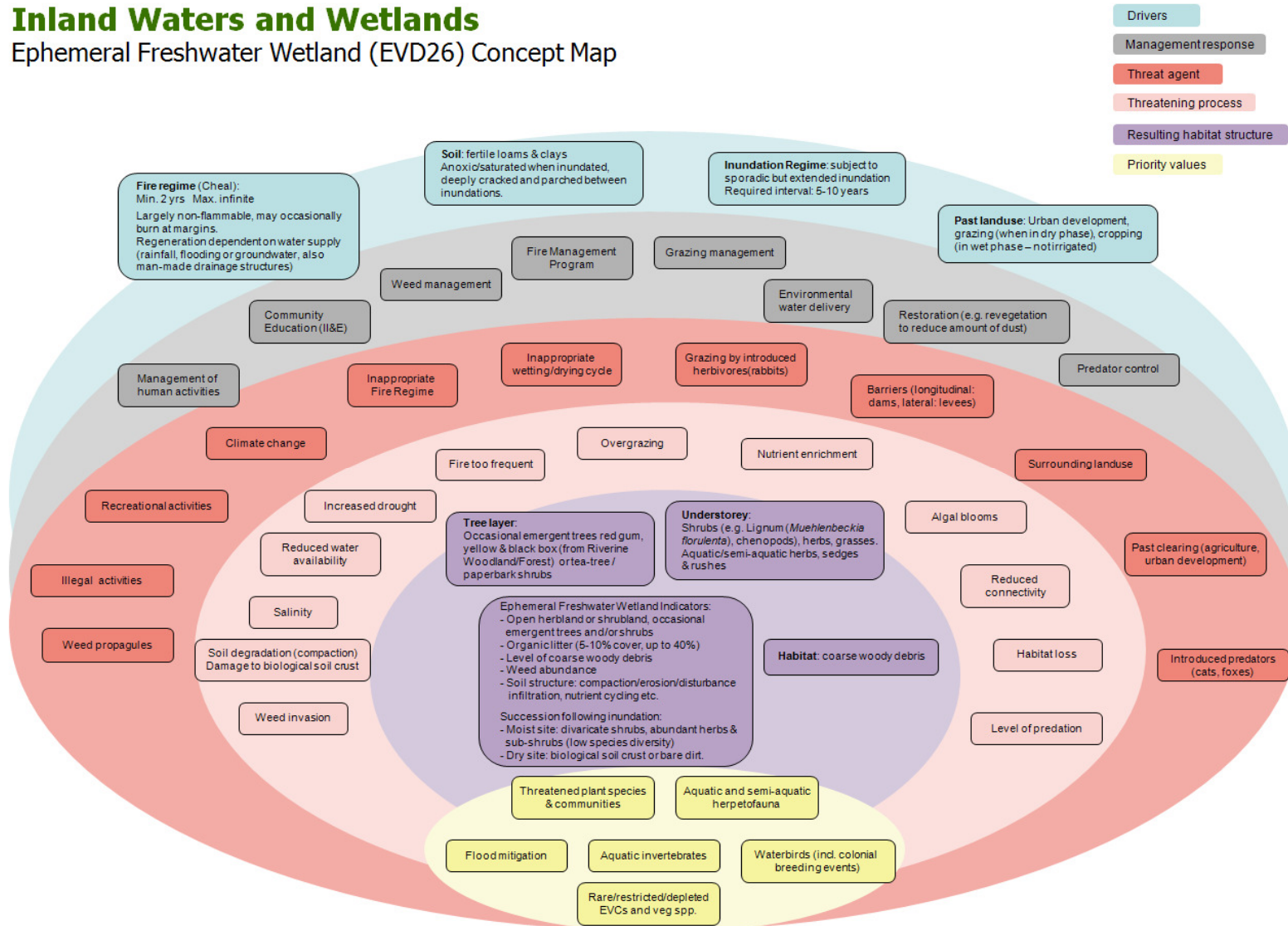
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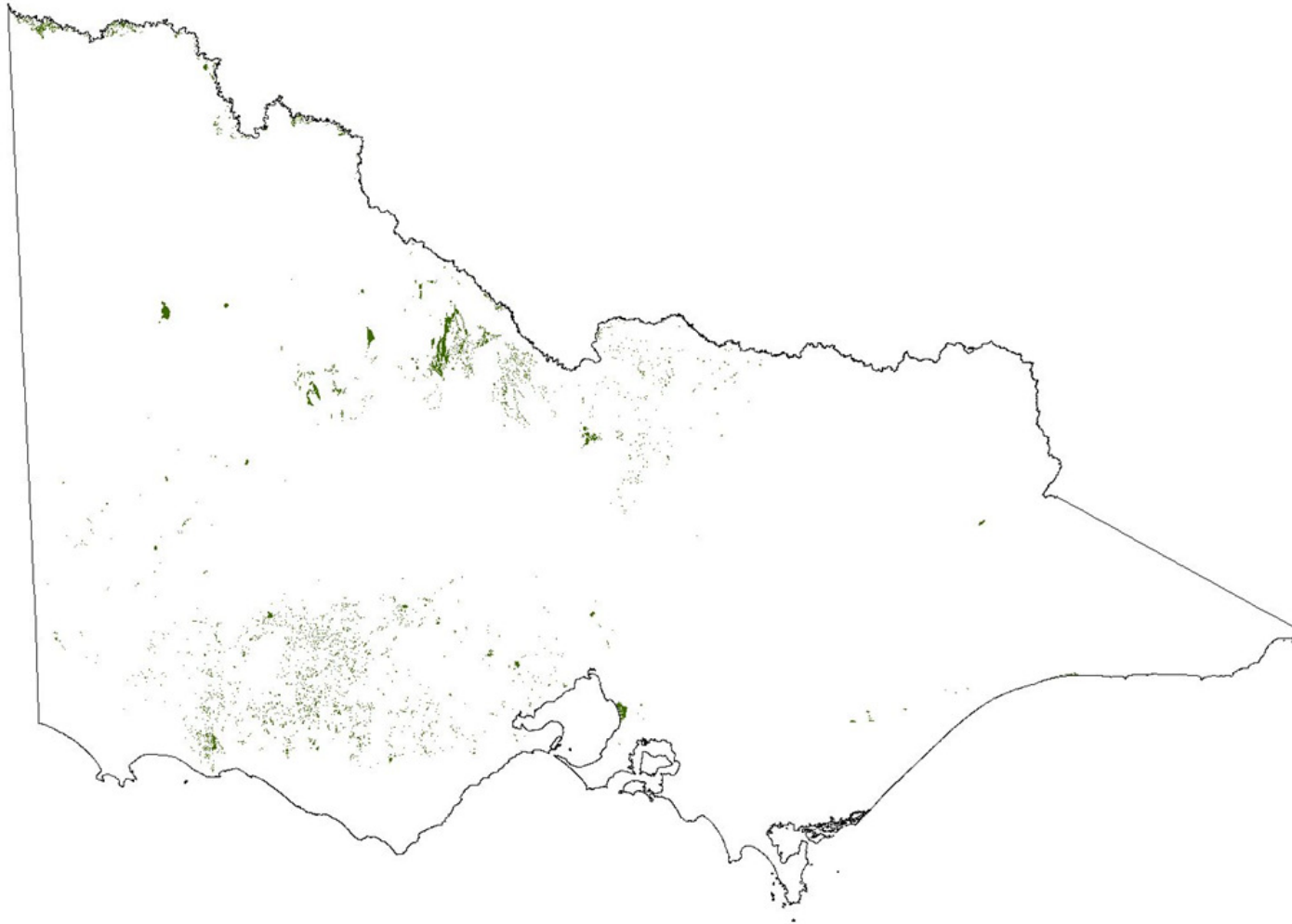
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Inland Waters and Wetlands

Ephemeral Freshwater Wetland (EVD26) Concept Map



EVD 26 Freshwater Wetland (Ephemeral)



100 0 100 200 Kilometers



A179

6.16. Inland Waters & Wetlands – Saline Wetland (EVD27)

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.16.1. Drivers

Fire regime: The minimum fire interval for low severity fires is 10 years and for high severity fires is 20 years; there is no upper limit for the fire interval; these systems are damaged even by rare fires (Cheal 2010). This ecosystem type is largely non-flammable, though it may burn at the margins.

Soil: Sodic (sodium affected), regularly moist (from tides and groundwater) with dry periods, high salinity at all times.

Inundation regime: Some saline wetlands require periodic flooding to enable recruitment (approximately every 5 years); water sources include natural and human-modified surface water, groundwater and direct rainfall.

Past landuse: This ecosystem type has been used for grazing, particularly when dry. They have also been used to store water that has been diverted (drained) from surrounding farmland and urban areas. Some systems also receive water from urban wastewater treatment.

Ecosystem productivity: Generally low, may be very high when in flood.

6.16.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native), and water. Weed species in this ecosystem type include Spear Thistle, Cat's Ear, Rye-grass, Water Buttons and grass species such as Tall Wheat Grass, Phalaris and Sweet Vernal Grass. Tall Wheat Grass is tolerant to saline conditions and is considered a serious weed when it invades wetland systems (Hale and Butcher 2010).

Illegal activities: These include the theft of flora and fauna, littering and off-road driving, riding and hiking, which can damage and/or remove vegetation and cause soil compaction and erosion. Dumping of hard rubbish is also an issue at some sites.

Recreational activities: These include fishing and duck hunting, the use of mountain bikes, motor bikes and cars (includes four-wheel driving in some areas), and boating, hiking and camping.

Climate change: Salt lakes are more susceptible to the impacts of climate change and altered water regimes than freshwater systems (Williams 1995), and are very sensitive to changes in the balance between inflows and evaporation (EPA 2010). The most important impact of climate change on these systems is likely to be increased drought, which will decrease water levels and increase salinity (Hale and Butcher 2010). The loss of water by evaporation (which is likely to increase with increasing temperatures) leads to increased

concentration of salts in the remaining water. Freshwater inflows dilute salts; however these are also likely to decline with the reduction in rainfall predicted with climate change.

Inappropriate water regime: These wetlands are typically continuously moist (due to their connection to groundwater and tides, both of which are saline), though large areas of standing water may only be present during flooding. Increased drought (likely under climate change) and/or further water resource development, will lead to lower water levels, increasing salinity. In addition, groundwater extraction results in a lowered watertable, and may lead to the wetland becoming disconnected from its groundwater source. Saline wetlands may receive increased flows from drainage of surrounding agricultural land, and also from urban wastewater treatment plants (Hale and Butcher 2010). An inappropriate water regime will result in changes to the composition and structure of native vegetation communities, and the loss of habitat for dependent fauna. The drying of saline wetlands causes a number of problems, including an excess of dust, which may have pollutants in it, and which may cause an amenity problem.

Inappropriate fire regime: The interval between fires may be too short (see above), leading to a change in the composition and structure of native vegetation, and the loss (or reduced abundance) of dependent fauna.

Inappropriate grazing regime: Grazing of stock at the margins of saline wetlands leads to soil compaction and erosion, increased nutrient input, changes to vegetation structure and composition and may also lead to the spreading of weed propagules.

Introduced herbivores: Includes rabbits and hare. Through preferential grazing and/or browsing introduced herbivores may change community structure and composition, inhibit regeneration, degrade water quality and cause soil disturbance and erosion.

Barriers (levees, dams/weirs): Saline wetlands may be affected by manipulations of the areas drainage and hydrology, this may lead to wetter or drier conditions than would otherwise occur, e.g. Western District Lakes are affected by an extensive drainage network which diverts water from adjacent agricultural land (Hale and Butcher 2010).

Surrounding landuse: Adjacent land use may include agriculture and urban development. Saline Wetlands are also vulnerable to the activities in the broader catchment area, such as the use of fertilizers, pesticides and herbicides; and the generation of sediment (a result of land clearing) and pollutants. Where the wetlands are terminal systems they act as sinks for pollutants which may include heavy metals (wastewater, leaching from old tip sites) and nitrogen and phosphorous (agricultural runoff). Surrounding land uses may include dairying, stock grazing, cropping and intensive animal husbandry (e.g. piggeries).

Past landuse: Clearing and disturbance in this ecosystem type is widespread. Vegetation has been removed for stock access, irrigation, industry, urban development and drainage control. Catchment clearing has also resulted in the modification and degradation of Saline Wetlands (runoff containing sediment and pollutants).

Introduced predators: Includes foxes and cats. These pose a predation risk to reptiles and ground nesting / ground feeding birds.

6.16.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions (e.g. bare ground, nutrient levels), and whether there are weed management strategies in place. Weeds have negative impacts on flora (competition and displacement) and dependent fauna.

Increased erosion and movement of soils, degradation of biological soil crust: Past land use / land clearing and the introduction of herbivores (managed and feral) have reduced the cover of vegetation and biological soil crusts, and increased soil disturbance, the amount of bare ground and the rate of soil erosion. Erosion has impacts on soil water storage capacity and water quality. Bare ground provides the opportunity for the invasion and establishment of weed plant species. Soil disturbance, erosion, and bare ground may also result from recreational activities, illegal activities (especially off-track activities) and fire.

Reduced water availability: This may result from extraction of water for human use (see Inappropriate Water Regime), and/or increased drought from climate change (see above).

Increased salinity: These wetlands are naturally saline; they receive water from saline groundwater and tidal movement. Salinity is at its lowest when water levels are at their highest (generally winter and spring). Any process which results in a decrease in water level concentrates salts and increases salinity. Increased salinity leads to a decline in invertebrate species richness and macrophyte diversity (Hale and Butcher 2010).

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter drought (CSIRO 2007). Increased drought will decrease water supply to wetlands, which in these systems will lead to decreased water levels and increased salinity (Hale and Butcher 2010). Other potential impacts of increased drought include a decrease in plant and animal recruitment; changes in flora and fauna diversity; change in litter production and decomposition rate; and increased fire severity and frequency.

Fire too frequent (interval too short): Fire interval less than 10 years for low severity fires and less than 20 years for high severity fires. Fire at intervals less than this may lead to changes in the composition and structure of vegetation for this ecosystem type, and the loss

(or reduced abundance) of dependant fauna. Too-frequent fire also contributes to increased soil degradation and erosion.

Overgrazing: Rabbits are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and increases cover and abundance of less palatable species. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and compaction, and contribute to conditions favourable to weed invasion (e.g. soil disturbance, the creation of bare ground).

Nutrient enrichment: Increased nutrient delivery to wetlands (particularly nitrogen and phosphorus) may result in eutrophication, and lead to an overgrowth of algae ('algal blooms'). Saline wetlands are to a large degree fed by runoff, which collects the fertilizers from the surrounding catchment. Some saline wetland systems also receive sewage water discharge, which can have high levels of phosphorous. Systems may be terminal with respect to surface water (without natural surface water discharge) so that flushing of nutrients, salts, and/or pollutants does not occur. [Note: they may be through flow systems with regard to groundwater (both receiving and discharging water to shallow groundwater aquifers) and may discharge nutrient and salts this way (Hale and Butcher 2010)].

Algal blooms: Algal blooms have amenity and health impacts, and reduce the level of dissolved oxygen in the water, resulting in the death of aquatic organisms. Algal blooms have become common-place in some areas (e.g. the Western District lakes regions, where they are occurring with increased severity and frequency (DNRE 2002)).

Habitat loss: Past land management has resulted in the loss and modification of this ecosystem type. Modifications to hydrology (patterns of drainage) have diverted water from some Saline Wetlands, and caused others to be wet for long periods (DNRE 2002). Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.16.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, based on the Key Fire Response Species (which are used to set the minimum and maximum fire intervals).

Grazing management: Grazing management in this ecosystem type would target introduced herbivores (rabbits and hare) and possibly also cattle. The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition/regeneration). It may also include the control of access to the wetland.

Environmental water delivery: It may be feasible to deliver environmental water to these systems; however the wetland would need to be close to other assets, e.g. creeks, river channels. The hydrological regime may also be manipulated by modifying artificially lowered outlets, and allowing diverted water to reach wetland systems (DNRE 2002).

Ex-situ catchment management: Wetlands within parks are affected by the activities that occur in the wider catchment area. These areas are managed by a variety of bodies that are guided by natural resource and catchment planning frameworks, which aim to address catchment-wide issues. Among these are programs to improve water quality and decrease sediment and nutrient delivery to waterways and wetlands.

Restoration: Different restoration methods are applied to the different ecosystem types. Restoration in this ecosystem type is likely to include revegetation.

Predator control: Monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species

occur that are vulnerable to predation. Another consideration in these systems is the water level in the wetland. When water levels fall, islands that formerly protected nesting and roosting waterbirds from foxes and cats may be eliminated (DNRE 2002).

6.16.5. Resultant Habitat Structure

Tree layer absent.

Open herbland to shrubland dominated by succulent herbs and shrubs, also rush and sedge species; including saltmarsh (e.g. beaded glasswort, Austral seablite and creeping boobialla) and sometimes Tea-Tree or Paperbark species. Adjoining unvegetated areas often salt-covered.

Aquatic/semi-aquatic plants: Limited submerged macrophytes, diversity decreases with increasing salinity. May include emergent littoral zone species such as *Phragmites australis* and submerged species such as *Ruppia* spp.

6.16.6. References

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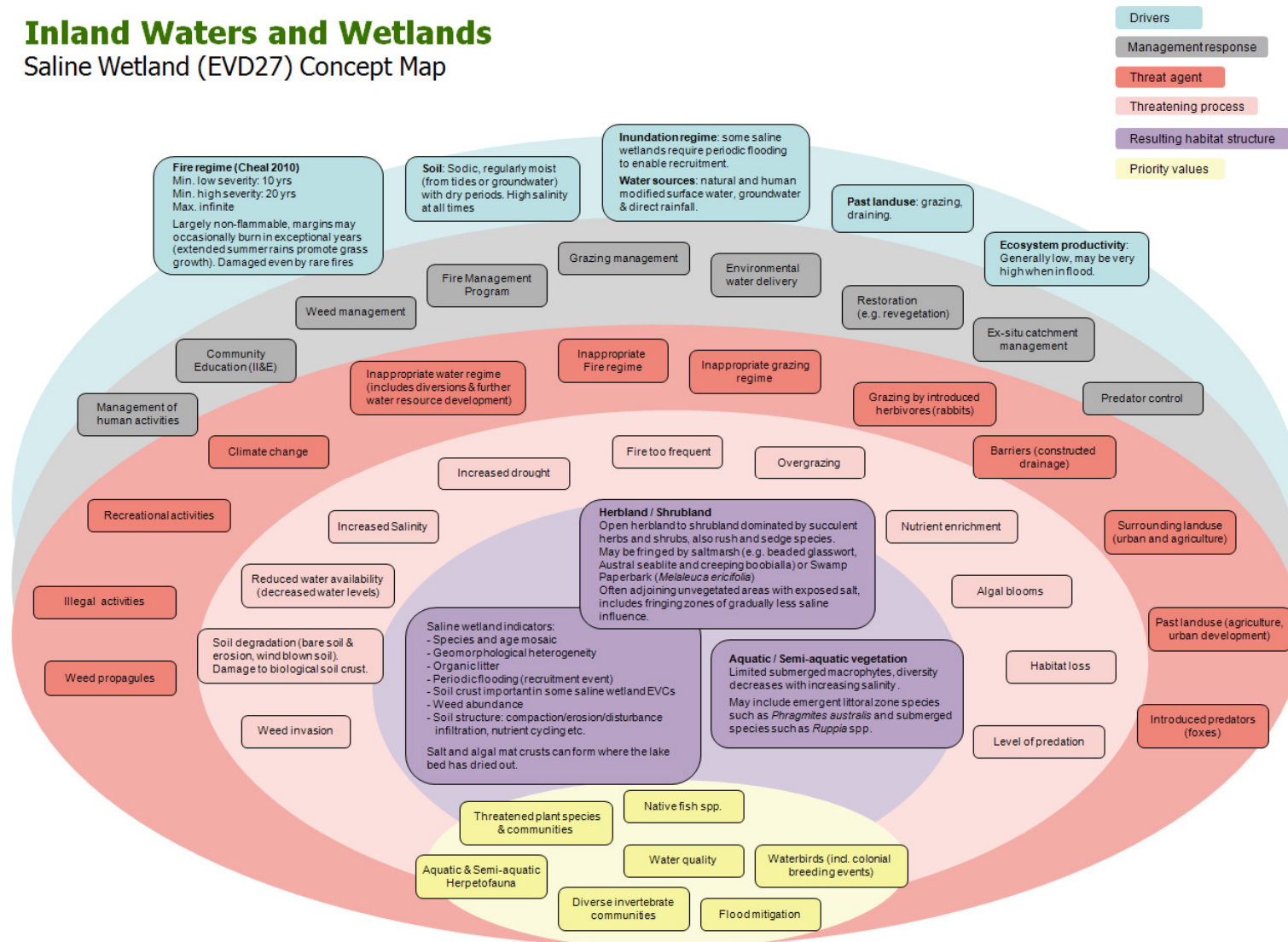
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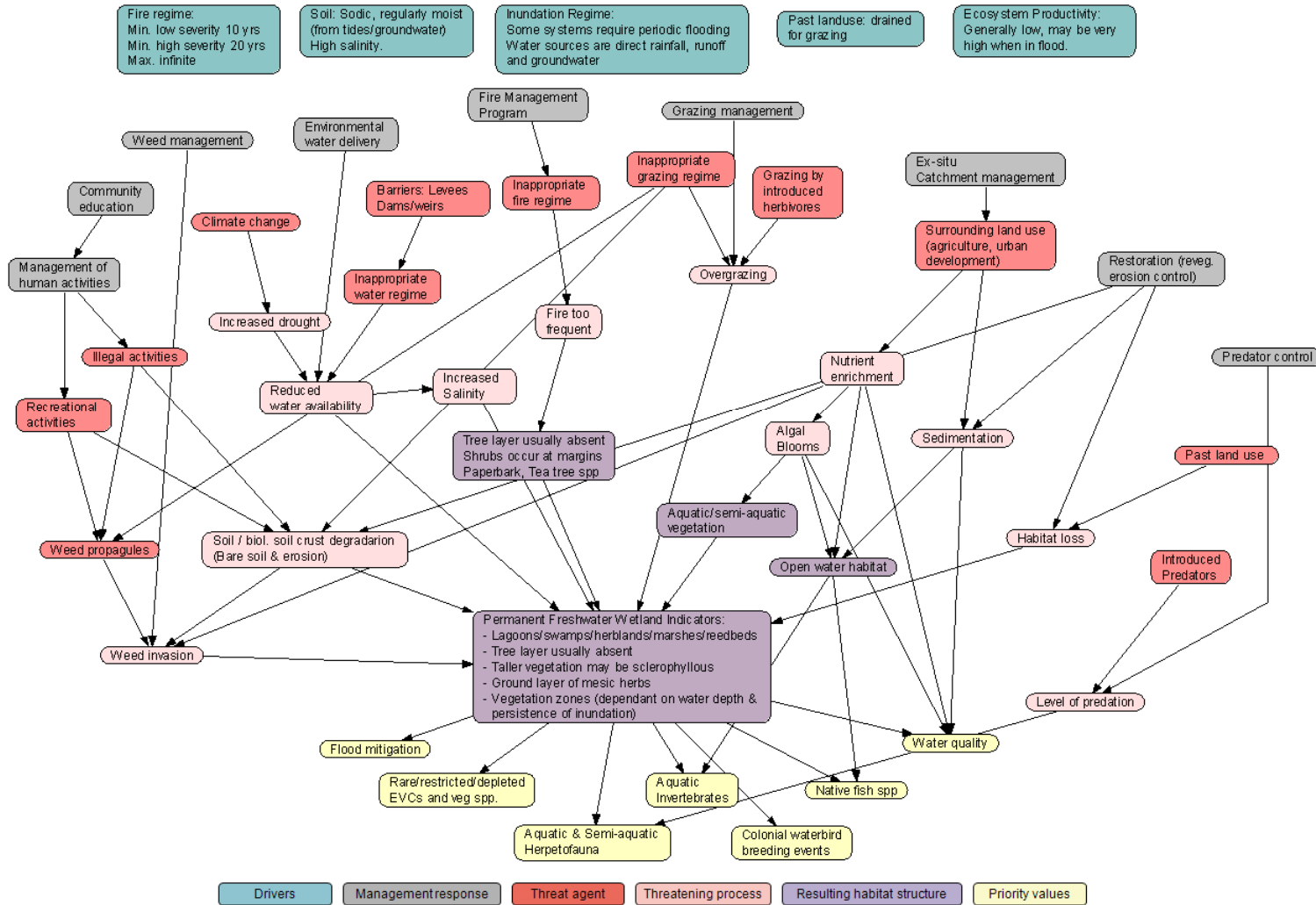
Inland Waters and Wetlands

Saline Wetland (EVD27) Concept Map

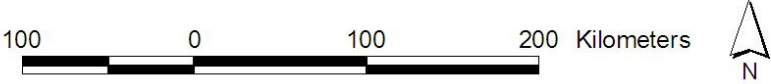
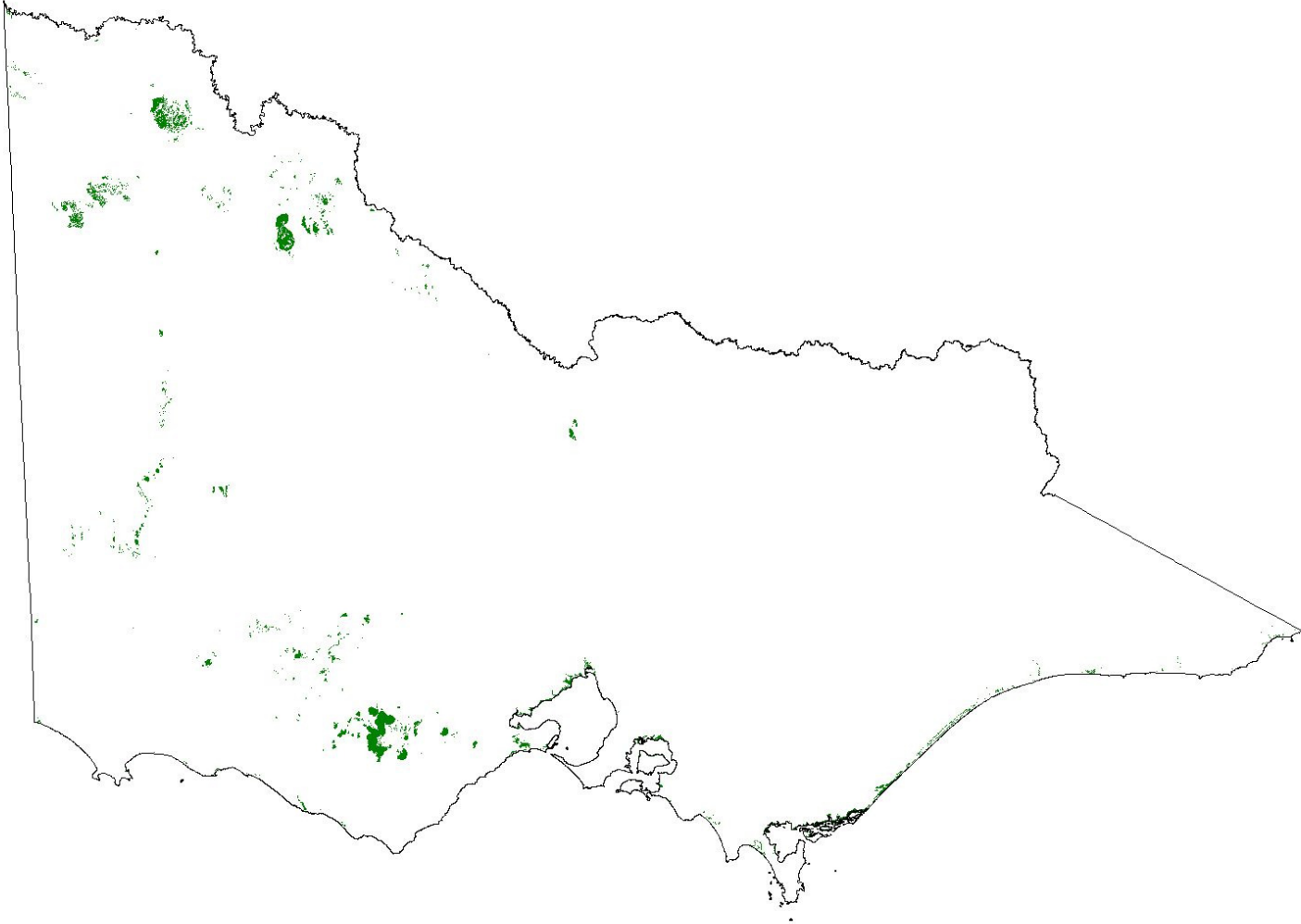


Inland Waters and Wetlands

Saline Wetland (EVD27) Causal Model



EVD 27 Saline Wetland



6.17.Coastal - Terrestrial (EVD1)

Includes terrestrial vegetation communities (grassland, woodland, scrub), excludes intertidal systems (rock platforms, saltmarsh and mangrove communities, estuaries, mudflats and seagrass beds).

Concept Map

Captures all of the variables that are important in determining the state or condition of the ecosystem under consideration. System components are spilt up into the following categories:

- **Drivers:** the things that determine the distribution of vegetation communities, and the main factors that act in these systems to influence their state or condition.
- **Threat agents:** the past and present activities (and other factors) at the start of a causal chain that ends with an effect on ecosystem structure, function, state or condition.
- **Threatening processes:** the process through which the threats influence system structure, function and state or condition.
- **Management responses:** Management actions that aim to eliminate/manage/ameliorate threats and threatening processes.
- **Resulting habitat structure** – the habitat that results from the combination of threats acting on a system and management responses:
 - Includes important habitat components (descriptive), e.g. tree layer, understorey, ground cover, tree hollows, woody debris, in-channel habitat.
 - Highlights the sorts of things that we could monitor in order to make a judgement about condition or state of a system.
- **Values:** PV-defined, are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

Causal models

These models have the same components as for the concept maps, but with links between components which indicate causal relationships. This captures important interactions as we understand them, but do not indicate if the relationship is positive or negative (i.e. if the node at the base of the arrow has a positive or negative influence on the node at the head of the arrow) and gives no indication of the magnitude of the effect.

6.17.1. Drivers

Fire regime: The vegetation types of this EVD are extremely variable in their fire susceptibilities, as reflected in the minimum and maximum tolerable fire intervals (Cheal 2010) outlined below. Scrub fires are often high severity, in woodland they may be high or low severity, and the grassland they are likely to be low severity, leaving many unburnt patches (Cheal 2010). The dominant species in this EVD have little capacity for resprouting, they are slow to recover, and regeneration is not generally fire-dependent (Cheal2010).

| | Maximum fire interval (yrs) | Min fire interval High severity (yrs) | Min fire interval Low severity (yrs) |
|-----------|-----------------------------|---------------------------------------|--------------------------------------|
| Grassland | 40 | 5 | 5 |
| Woodland | 70 | 25 | 10 |
| Scrub | 90 | 10 | 10 |

Soil: Soils in this EVD are predominantly sandy and often unconsolidated, they are also well drained with poor water-holding capacity and low fertility.

Past landuse: Clearing and disturbance in this ecosystem type is widespread. Vegetation has been removed for beach access, settlement, grazing, recreation and fishing. Vegetation composition and structure has been modified by altered fire regimes.

Ecosystem productivity: Generally low.

6.17.2. Threat Agents

Weed propagules: Vectors for movement of weed propagules include human activities and herbivores (introduced and native), and water. Weed species in this ecosystem type include thistles (e.g. Spear Thistle, Common Sow Thistle), daisies (e.g. Ragwort, Boneseed), annual and perennial grasses (e.g. Yorkshire Fog), shrubs (e.g. *Coprosma repens*) and climbers (e.g. Asparagus). Marram grass (*Ammophila arenaria*) was actively planted to stabilise eroding dune systems in some areas. Sea Spurge is a particularly invasive species on coastal dunes. Some native species have increased in abundance since European settlement and may be considered environmental weeds in some areas (Coast Tea-tree and Coast Wattle). Due to the natural disturbance cycles in this environment (sandy soils coupled with storm and wave activity) coastal habitats tend to be vulnerable to weed invasion.

Illegal activities: These include the theft of flora and fauna, littering and off-road driving (includes trail-bike riding and four-wheel driving), which can damage and/or remove vegetation and cause erosion.

Recreational activities: These include fishing, horse riding, hiking and camping. Vegetation has been removed for beach access, and the often extensive network of active and disused walking and vehicle tracks provides a means of access for predator species and the opportunity for erosion and weed invasion (PV 1998).

Climate change: Climate change is likely to be a major threat to coastal ecosystems. Sea level rise (Bates et al. 2008) and increased storm activity (IPCC 2007) are predicted and are likely to affect coastal systems. Impacts include increased inundation and rates of coastal erosion, and salt water intrusion into coastal groundwater systems (exacerbated by the reduction in freshwater input due to decreased runoff and increased drought). The shoreward movement of habitat zones is not possible in many situations due to existing coastal development (Edmunds et al. 2010).

Inappropriate fire regime: The interval between fires may be too short or too long (see above), leading to a change in the composition and structure of native vegetation, and the loss (or reduced abundance) of dependent fauna. Fire regimes which maintain areas at a range of ages are required to provide habitat for both early (e.g. many orchids) and late (e.g. Rufous Bristle bird and Swamp Antechinus) post-fire successional specialists (PV 1998).

Phytophthora: *Phytophthora cinnamomi* is a water mould that attacks the root systems of susceptible native plant species, causing plant mortality. This can change the composition and structure of native vegetation communities, and result in the loss of habitat for dependent fauna. Rainfall, temperature and soil characteristics determine the distribution of Phytophthora (warm, wet soils with impeded drainage are ideal). Susceptible plant families are Proteaceae (e.g. *Grevillea*, *Banksia*), Fabaceae (peas), Dilleniaceae (e.g. *Hibbertia*) and Epacridaceae (heaths) (DSE 2008). Phytophthora has been recorded in a number of parks with this ecosystem type (e.g. Cape Conran) and is a recognised problem in coastal areas of Gippsland (PV 2005a).

Introduced herbivores: Includes rabbits, goats, pigs, Fallow Deer and Hog Deer. Through preferential grazing and/or browsing introduced herbivores may change community structure and composition, inhibit regeneration and cause soil disturbance and erosion.

Surrounding landuse: Adjacent land use includes grazing and dairying, recreation and urban development (with the pressure for coastal development increasing, Edmunds et al. 2010). A number of weed species are garden escapes (e.g. Cape Ivy, Arum Lily, Dolichos Pea, English Ivy, Watsonia, Agapanthus and Blue Periwinkle PV 2003), which is indicative of

the close proximity of this ecosystem type with urban areas and the lack of native vegetation buffers (PV 2005b).

Past clearing: Clearing and disturbance in this ecosystem type is widespread. Vegetation has been removed for beach access, settlement, grazing, recreation and fishing.

Introduced predators: Includes foxes, dogs and cats. These pose a predation risk to ground nesting birds and small mammals.

6.17.3. Threatening Processes

Weed invasion: This variable refers to weed distribution and abundance, which is influenced by the presence and abundance of weed propagules, site conditions (e.g. bare ground, nutrient levels), and whether there are weed management strategies in place. Weeds have negative impacts on flora (competition and displacement) and dependent fauna.

Increased erosion and movement of soils: Vegetation cover is particularly important in this ecosystem type as the soils are sandy and tend to be unconsolidated, and hence they are potentially very mobile. Species such as Hairy Spinifex (*Spinifex sericeus*) and Coast Tussock-grass (*Poa poiformis*) help to stabilise the sandy soils and establish conditions suitable for other species to establish. Due to the natural features of this environment (sandy soils coupled with storm and wave activity) coastal habitats tend to be prone to erosion. Soil disturbance, erosion, and bare ground may also result from recreational activities, illegal activities (especially off-track activities) and fire. Past land use / land clearing and the introduction of herbivores (managed and feral) have reduced the cover of vegetation in this ecosystem type, and increased soil disturbance, the amount of bare ground and the rate of soil erosion. Bare ground provides the opportunity for the invasion and establishment of weed plant species.

Sea level rise: Global mean sea level is expected to increase by between 0.18 m and 0.59 m by the end of the century (Bates et al. 2008). Potential impacts include salinisation of groundwater (coastal aquifers) and increased coastal inundation and erosion. Impacts of sea level rise on flora and fauna are likely to be exacerbated by coastal development and population growth (IPCC 2007), as the movement of suitable conditions for coastal vegetation (and intertidal habitats) move shoreward.

Increased drought: Climate change projections for southern Australia include more frequent, longer and hotter drought (CSIRO 2007). Impacts of increased drought include decreased runoff, decreased plant and animal recruitment; changes in flora and fauna diversity; change in litter production and decomposition rate; and increased fire severity and frequency.

Fire too frequent (interval too short): Too-frequent fire leads to changes in the composition and structure of vegetation, the loss (or reduced abundance) of dependent fauna, and may also contribute to increased soil degradation and erosion.

Fire not frequent enough (interval too long): Fire intervals greater than the maximum tolerable fire intervals (see above) lead to changes in vegetation composition and structure, some of these changes may be irreversible. In addition, some plant species may become weedy in the absence of fire (e.g. Coast Wattle and Coast Tea-tree).

Overgrazing: Rabbits are a potential issue in this ecosystem type. Overgrazing reduces the cover and abundance of palatable species and inhibits regeneration. This results in change to vegetation structure and composition, and the modification of fauna habitat. Overgrazing may also contribute to soil erosion and conditions favourable to weed invasion.

Habitat loss: Past clearing and land management practices have resulted in the loss and modification of this ecosystem type. Existing habitat may also be under pressure from degrading processes which can contribute to further habitat loss.

Fragmentation: The clearing of native vegetation has resulted in the creation of isolated patches (or fragments) of habitat. This ecosystem type was extensively cleared and the remnants are now highly fragmented. Fragmentation isolates fauna and flora species, which results in reduced recruitment and may lead to local extinctions. Internal fragmentation (from walking tracks and management tracks) may also be an issue.

Edge effects: Coastal vegetation (and coastal parks) typically occur in comparatively narrow zones parallel to the coast line. This results in a higher edge-to-area ratio (high ratio of park boundary compared to park area) and increased exposure to weed propagules, insect attack, predator incursions, nutrient enrichment and soil disturbance. Edge effects may also occur in response to roads and walking tracks, tourist facilities, and land clearance on adjacent land. Biota at or near the edge of an area of remnant vegetation may be affected by changes in the microclimate (e.g. fluxes of wind, radiation and water). Edge effects in coastal parks are exacerbated by the absence of native vegetation buffers on the park boundary, i.e. where urban and agricultural land occurs right up to the park boundary (e.g. in the Bay of Island Coastal Park, PV 1998).

Level of predation: This refers to the total pressure on key fauna populations from predation, rather than simply the presence or absence of predator species. The idea is that introduced predators may be present in an area, but may not be having an impact on prey species that is considered significant. The level of predation is estimated by monitoring predator abundance and activity levels and trends in the abundance of prey species.

6.17.4. Management Responses

Community Education (II&E): The Information, Interpretation and Education (II&E) program is the framework used to inform visitors, foster community understanding and appreciation, build understanding of management and help visitors to enjoy their visits.

Management of human activities: These include the activities of visitors, adjoining landowners and the local community. The activities may be either recreational or illegal activities. Several education programs are in place to inform and motivate people to look after the park and native plants and wildlife.

Weed management: Weeds are managed using a variety of methods, including herbicides, physical or mechanical control (mowing, grazing, mulching, burning, manual removal), and biological control (using the plants natural enemies). Any weed management strategy should aim to reduce the extent of weeds, and weed seed stock in the soil, and also reduce the suitability of site conditions for weed invasion.

Fire management program: Fire management is based on ecological considerations and the protection of life and property. Ecological considerations are usually based around the maintenance of plant species typical of a particular vegetation type, based on the Key Fire Response Species (which are used to set the minimum and maximum tolerable fire intervals).

Grazing management: Grazing management in this ecosystem type would target introduced herbivores (rabbits and hare) and possibly also cattle. The key consideration is the overall grazing pressure as determined from monitoring of key indicators (e.g. vegetation condition/regeneration).

Restoration: Different restoration methods are applied to the different ecosystem types. Restoration in this ecosystem type is likely to include revegetation and erosion control in coastal dunes (e.g. PV 2006).

Phytophthora containment & hygiene measures: Containment and hygiene measures are used to minimise the spread of *Phytophthora cinnamomi*. Procedures include management (or minimization) of movement of people, vehicles, equipment and other materials from infested into uninfested sites, and may include wash-down facilities. Other considerations include road placement, movement of gravel, road grading operations, drainage and management of vehicle tracks and fire operations.

Predator control: Monitoring and predator control programs are guided by management and conservations objectives, resource availability, time constraints and site characteristics. Control programs are generally undertaken where threatened or locally significant species

occur that are vulnerable to predation. Significant species that are vulnerable to predation include the Little Tern and Hooded Plover, which nest on exposed beaches (PV 2005a).

6.17.5. Resultant Habitat Structure

Grassland: grasses, herbs (many succulent), sedges and scramblers. Species include Coast Tussock-grass (*Poa poiformis*), *Spinifex sericeus*, Seaberry Saltbush (*Rhagodia candolleana*), Karkalla (*Carpobrotus rossii*), and Coast Saltbush (*Atriplex cinerea*).

Woodland: occurs in the protected areas between and behind sand dunes. Species include Silver Banksia (*B. marginata*), Saw Banksia (*B. serrata*), Coast Banksia (*B. integrifolia* ssp. *integrifolia*), and *Eucalyptus botryoides*.

Scrub: open herblands to closed shrublands, species include Coast Tea-tree (*Leptospermum laevigatum*), Coast Beard-heath (*Luecopogon parviflorus*), Drooping Sheoke (*Allocasuarina verticillata*), Coast Wattle (*Acacia longifolia*), Swamp Paperbark (*Melaleuca ericifolia*), and Moonah (*M. lanceolata*). Ground layer includes sedges, grasses and herbs.

Hollows: The number and size of tree hollows depend on the age of the tree species and therefore the time since the last disturbance (e.g. clearing, fire).

Woody debris: The amount of woody debris is determined by the rate at which it is produced (it takes longer to build up in low productivity forests and woodlands) and the rate at which it is lost from the system (e.g. firewood collection, fire).

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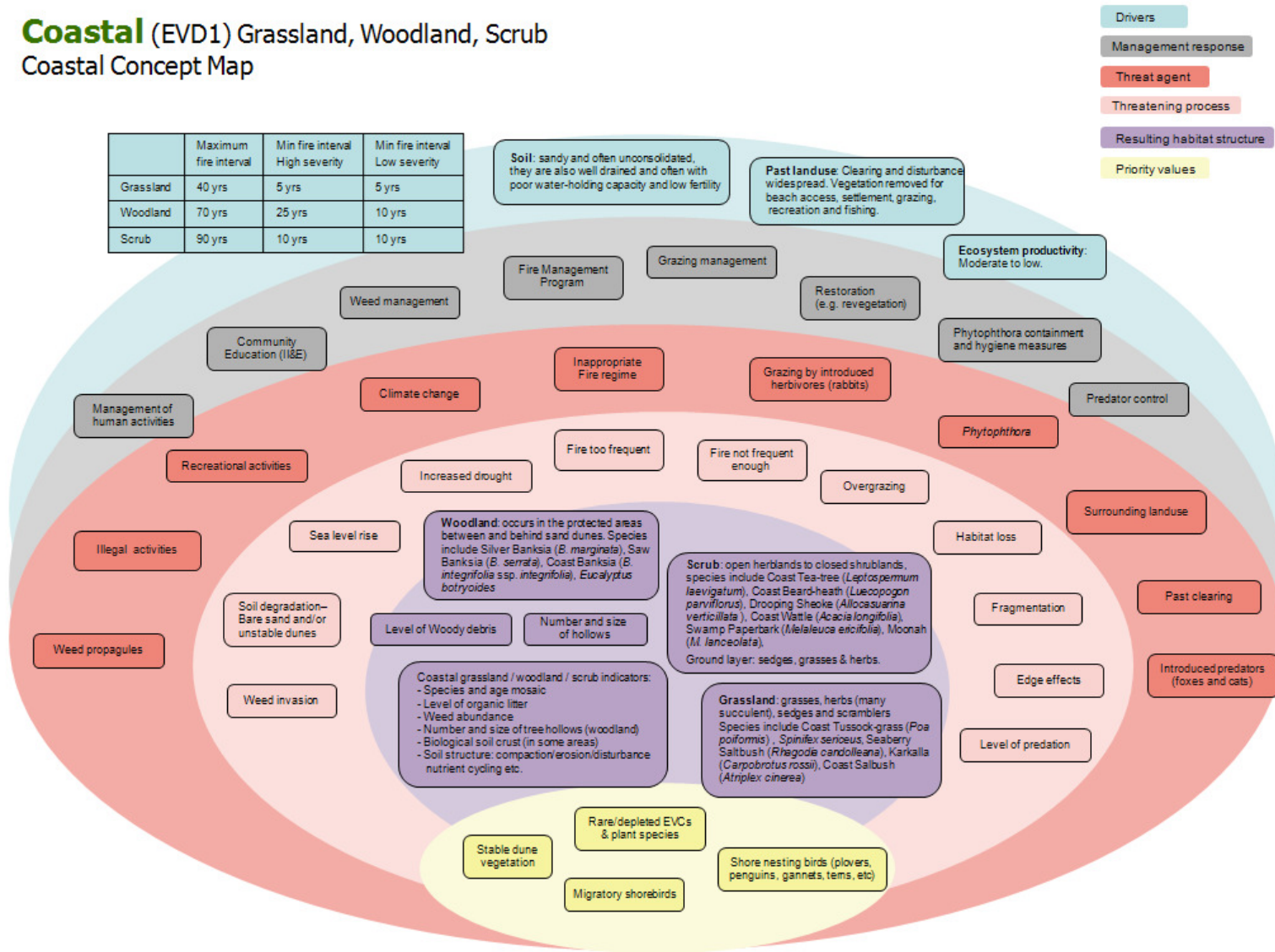
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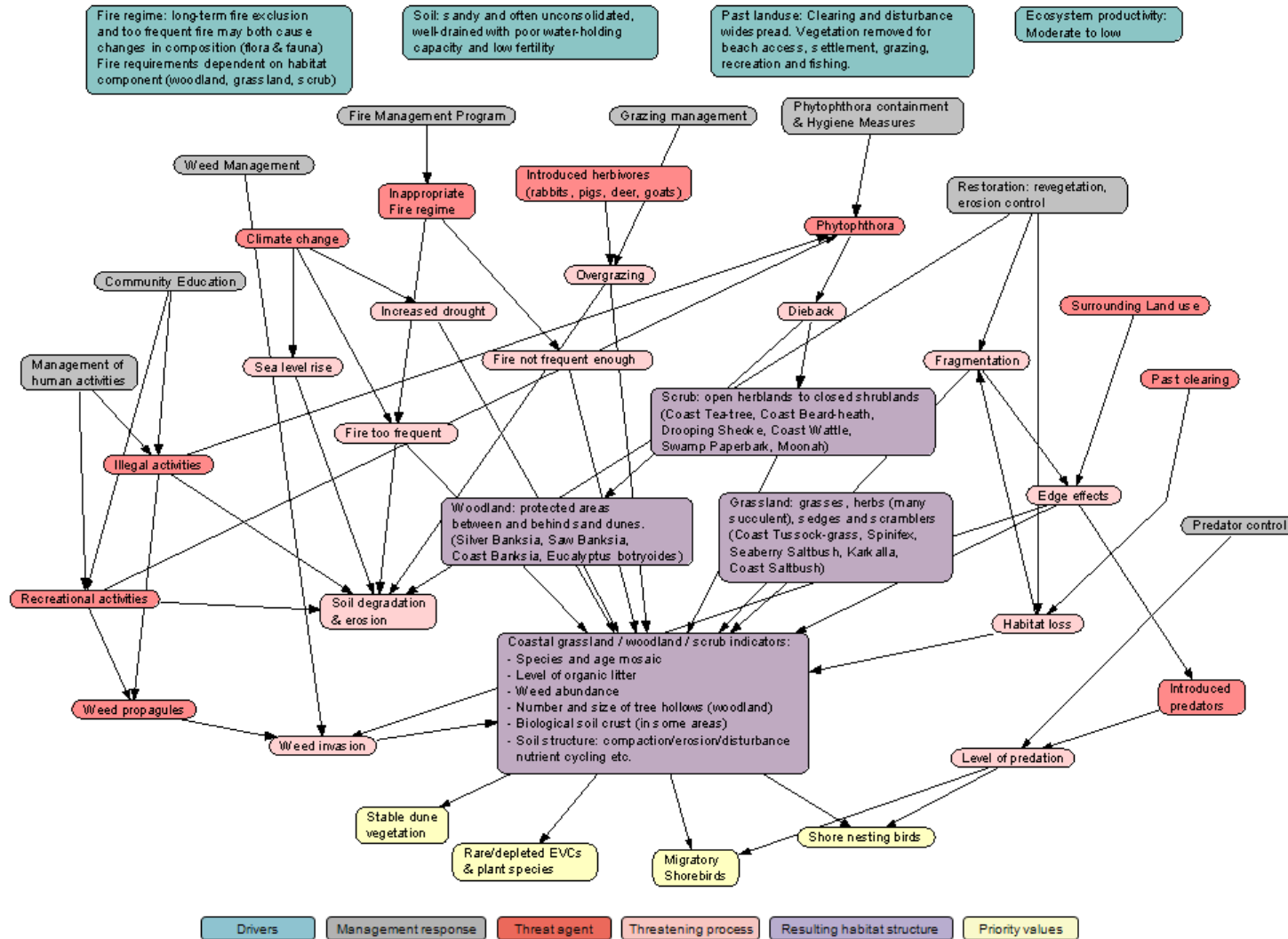
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Coastal (EVD1) Grassland, Woodland, Scrub Coastal Concept Map

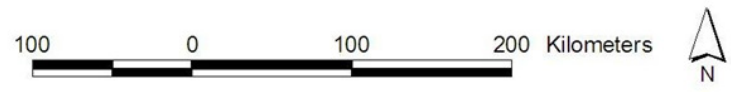
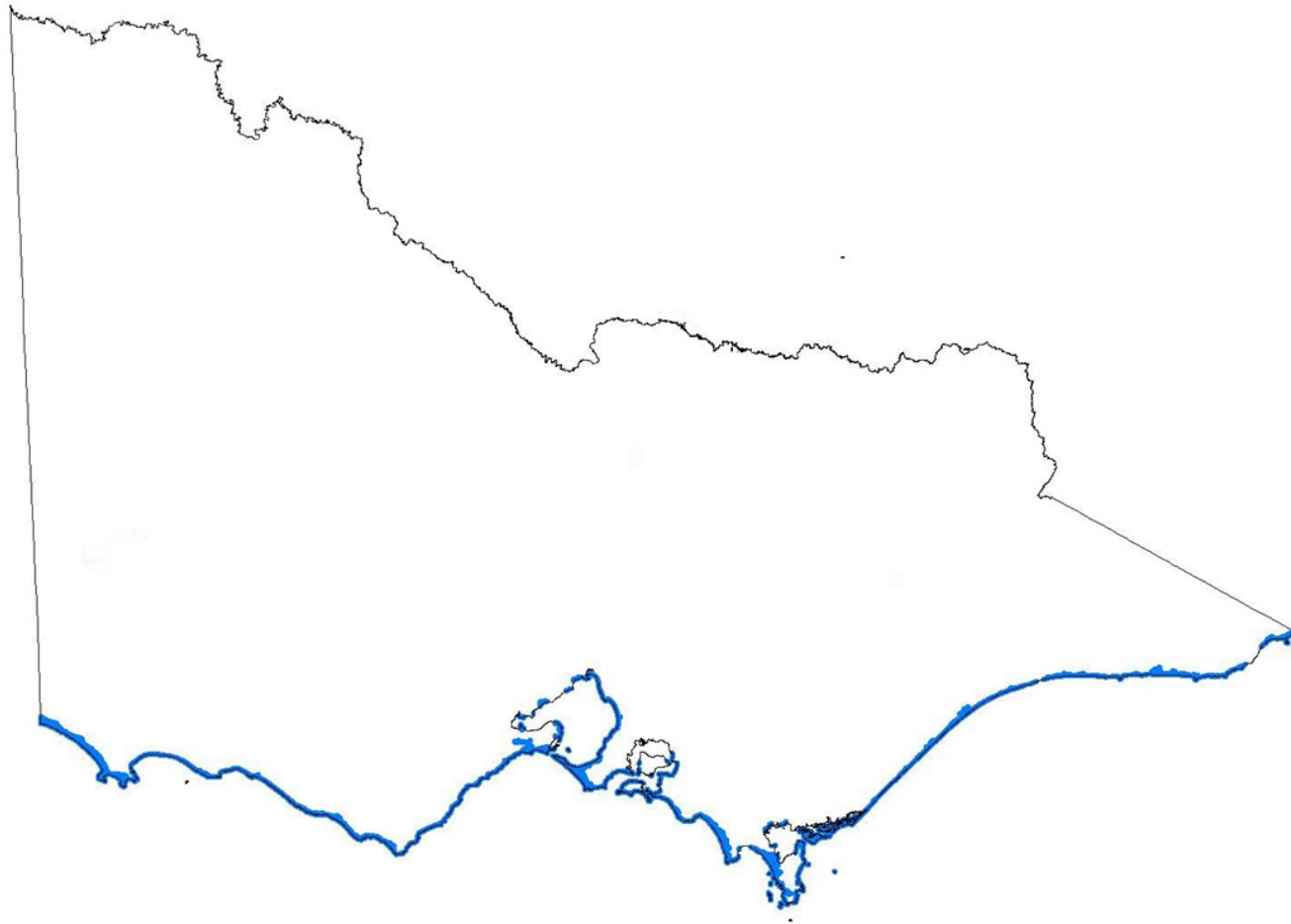


Coastal (EVD1) Grassland, Woodland, Scrub

Coastal Causal Model



EDV 1 Coastal



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