# Vegetation responses to stock exclusion: synthesis report

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**Acknowledgment**

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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**Front cover photo**: Scientist monitoring mallee investment site (Claire Moxham) and fenceline comparison of an ungrazed investment sites and a grazed paddock (Declan Leevers).



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# Vegetation responses to stock exclusion: synthesis report

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Data used in this project were collated from a range of project sources, in particular those monitoring projects undertaken by Catchment Management Authorities and DELWP.

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# Summary


## Context

The State Government makes significant investment into on-ground actions to benefit biodiversity and restore the natural environment. Almost one third of Victoria's remaining native vegetation is in the private estate. On private land, the main management intervention is livestock exclusion through fencing to improve native vegetation outcomes. Improving and reporting on these outcomes is dependent upon accurate evidence-based data to support the implementation of management interventions. Currently, there is little information available that evaluates the success of these investment programs in achieving the desired biodiversity outcomes.

The objective of the four-year Adaptive Learning project is to support and improve the collection of evidence to test investment assumptions to enable reporting on investment program outcomes and to demonstrate effectiveness to investors and stakeholders. This report provides a synthesis of the outcomes for the 'Vegetation responses to stock exclusion fencing' sub-project. A series of related factsheets, an unpublished reports and scientific publications have also been delivered as part of this sub-project.

## Aims

- Contribute to refining of models that inform the relationships between management interventions (especially stock exclusion fencing), threat mitigation (inappropriate grazing) and asset condition (native vegetation).
- Communicate the findings from this sub-project to relevant land managers and stakeholders to better inform decisions for on-ground management interventions through an adaptive management framework.
- Support decision making for future investment programs.

## Findings

A series of meta-analyses that contribute to filling key knowledge gaps and validating the assumptions of models with real data have been developed. The meta-analyses investigated expected responses for a range of native vegetation components (e.g. species, functional groups), that are not well understood over a variety of environmental factors and external drivers. This is an effective approach to examining the role of native vegetation management intervention programs.

On-ground assessments of vegetation and ground layer attributes indicate that native vegetation investment programs implementing stock exclusion fencing have generally maintained or improved vegetation condition. Unsurprisingly, changes in vegetation condition were also influenced by external drivers (e.g. annual rainfall and landscape context) as well as vegetation type and starting condition. Expected and observed vegetation responses differed, and differences were often influenced by site-specific drivers.

## Conclusions and implications

A range of considerations for improving future investment programs' native vegetation outcomes are discussed in this report. These include:

- A framework for investment priorities.
- Considerations to improve future investment program outcomes.
- Expected and observed vegetation responses to stock exclusion fencing.
- Actions to improve management plans and other interventions to maximise native vegetation outcomes.
- Remaining knowledge gaps, future research and monitoring.

The outcomes of this project can improve future monitoring and investment programs by making more accurate predictions of native vegetation responses across different scenarios over both the short- and long-term, this will directly contribute to Protecting Victoria's Environment - Biodiversity 2037.

Data and findings from this project will inform expert opinion to refine future Strategic Management Prospects modelling.

In a highly variable environment, collection of long-term data is required to fully evaluate native vegetation responses to stock exclusion fencing.

# 1 Introduction

## 1.1 Project context

### 1.1.1 Background

Almost one third (approximately 1.1 million hectares) of Victoria's remaining native vegetation is on private land (DSE 2011), much of which is of high conservation significance. Native vegetation on the private estate supports 30% of Victoria's threatened species populations (CES 2008) and provides many ecological services such as erosion control and improved water quality. Hence, the management of native vegetation on private land is important to maintain functioning ecosystems and to achieve landscape-scale conservation outcomes in the agricultural matrix (Lindenmayer *et al*. 2012).

The Department of Environment, Land, Water and Planning (DELWP) makes significant investments in on-ground management actions to benefit biodiversity and the State's natural environment, particularly in the private estate. The ability to achieve these benefits to biodiversity depends upon reliable and accurate information to understand the role of these actions and support their future application.

The objective of the four-year Adaptive Learning project is to support and improve the collection of evidence to test assumptions about the relationships between management intervention, threat mitigation and asset condition and to enable reporting on program outcomes and effectiveness to investors and stakeholders. The Adaptive Learning project includes assessment of the effectiveness of on-ground actions to demonstrate impact, and coordination of data and information to be used for future decision making. Four research areas were identified: (1) vegetation responses to stock exclusion fencing, (2) predator control effectiveness, (3) revegetation outcomes, and (4) engaging the community in biodiversity data collection through citizen science.

This report is a component of the Adaptive Learning subproject 'Vegetation responses to stock exclusion fencing'. This subproject refines the assumptions that influence the model describing the relationships between management interventions, threat mitigation and asset condition (Figure 1), with the aim of using these improved models to better inform on-ground outcomes, management practices and future investment programs.

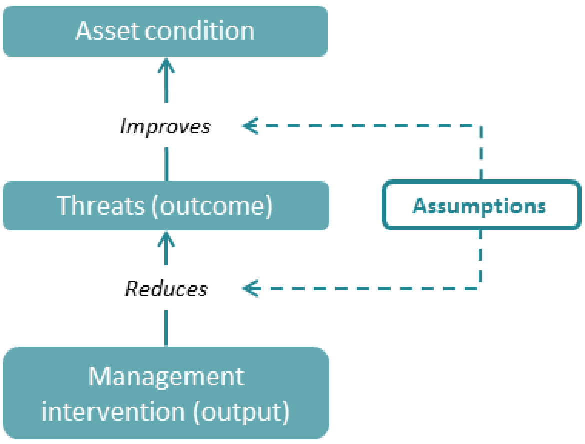



**Figure 1. The conceptual model of relationships and assumptions between program outputs (management interventions), the expected outcomes (threat mitigation) and asset condition (e.g. native vegetation).**

**Vegetation responses to stock exclusion**

Grazing by herbivores (notably domestic livestock) often has detrimental effects on native flora and fauna (Lunt et al. 2007). Thus, stock exclusion fencing is the recommended management intervention to address the primary threat (i.e. grazing) and to improve vegetation condition. DELWP makes significant investments to provide for fencing of remnant vegetation to control grazing pressure and achieve predicted conservation benefits (Moxham et al. 2015; Moxham and Fanson 2018). However, an uncertainty analysis using DELWP's biodiversity decision support tool, Strategic Management Prospects (SMP), showed that the expert elicited benefits of stock exclusion fencing had a very high level of uncertainty (Thomson 2017). That is, there is limited knowledge about where, and in what circumstances, management interventions should be carried out to improve biodiversity outcomes. The expected responses for a range of plant community components (e.g. individual species, woody species, various functional groups), are not well-understood over a range of environmental factors (e.g. productivity gradients), external drivers (e.g. climate) and management scenarios (e.g. intensity of historical management). Furthermore, there are no predictive models about the expected vegetation responses across a range of scenarios that can be used to guide management activities such that vegetation condition will be improved over different temporal and spatial scales.

To address this uncertainty, this project aims to inform key knowledge gaps on vegetation responses to stock exclusion. It will contribute to refining the models used to evaluate the relationships between management interventions, threat mitigation and native vegetation condition. Project findings will directly contribute to:

- Validating expert opinion to refine future Strategic Management Prospects modelling;
- Supporting improved decision making, by contributing to state-wide targets and to meeting the goals of Protecting Victoria's Environment – Biodiversity 2037; and
- Informing on-ground actions and management interventions through an adaptive management framework, as well as future investment programs.

### 1.1.2 Background - Stock exclusion fencing

In southeastern Australia, grazing by stock is one of the main threatening processes to retention of native vegetation in the private estate (MCMA 2006). Continuous, or set stocking, is by far the most commonly applied grazing system in Australia's management history (Earl and Jones 1996). This land use strategy threatens the viability of remnant native vegetation on many Victorian farms. Inappropriate grazing regimes (e.g. set stocking, over grazing) can alter processes and vegetation function which results in ecosystem degradation (Asner et al. 2004) and threatens native vegetation (Jones 2000; Asner et al. 2004; Lunt et al. 2007a; Jing et al. 2013; Xiong et al. 2016). Altered processes include altered soil properties (e.g. erosion, soil compaction; Jones 2000; Lui et al. 2017), altered nutrient levels and cycling (Cheng et al. 2016; Xiong *et al.* 2016), increased weed abundance (Moxham et al. 2017), and loss of native species (Lunt et al. 2007a; Merriam et al. 2017). The private land estate is particularly vulnerable to these threats (Lunt et al. 2007a).

Governments make significant investment in on-ground management interventions, such as stock exclusion fencing, that aim to benefit biodiversity and the natural environment (Ferraro and Kiss 2002; Donald and Evans 2006). Land protection is important as many vegetation types in the private estate also contain threatened species and plant communities (Zimmer et al. 2010), and restoration efforts can achieve landscape scale conservation outcomes in the agricultural matrix (Lindenmayer *et al.* 2012). Stock exclusion fencing is a simple and effective intervention which is an important first step in protecting remnant native vegetation from the impacts of stock grazing which can promote weed invasion, reduce tree recruitment and alter vegetation structure (Spooner et al. 2002; Lunt *et al.* 2007a). Success is dependent on substantial efforts by private landholders, who are supported by a range of incentive and extension schemes to implement on-ground management interventions.

In Victoria, a key management intervention to maintain or increase biodiversity values in the private estate is the removal of stock grazing through stock exclusion fencing (Spooner et al. 2002; Mata-Gonzalez et al. 2007; Lunt et al. 2007a; Jing et al. 2013; Mofidi *et al*. 2013). Since the 1980s stock exclusion fencing has been undertaken by Victorian Government investment programs, particularly on private land, to maintain or improve vegetation condition. Incentive programs (e.g. BushTender, EcoTender) have provided funds to landholders to fence remnant native vegetation on private land in order to reduce the impacts of stock grazing and improve vegetation condition (Spooner et al. 2002; Briggs et al. 2008; Spooner and Briggs 2008; Prober et al. 2011).

**Broad management objectives**

In the first instance, investments in stock exclusion fencing aim to release native vegetation from the negative impacts of grazing and as a result maintain or improve overall vegetation condition (Briggs et al. 2008; Figure 2). The goal is restoring the vegetation to a preferred state, based on conservation objectives, which existed prior to grazing occurring. In Victoria, this is defined as the Ecological Vegetation Class benchmark state (Parkes et al. 2003). It is expected that the following changes in vegetation condition will occur over time after the removal of stock grazing (Figure 2):

- Increased native vegetation abundance;
- Increased native vegetation structural integrity;
- Increased native vegetation richness;
- Increased woody species recruitment;
- Decreased exotic vegetation abundance; and
- Decreased or altered bare ground.

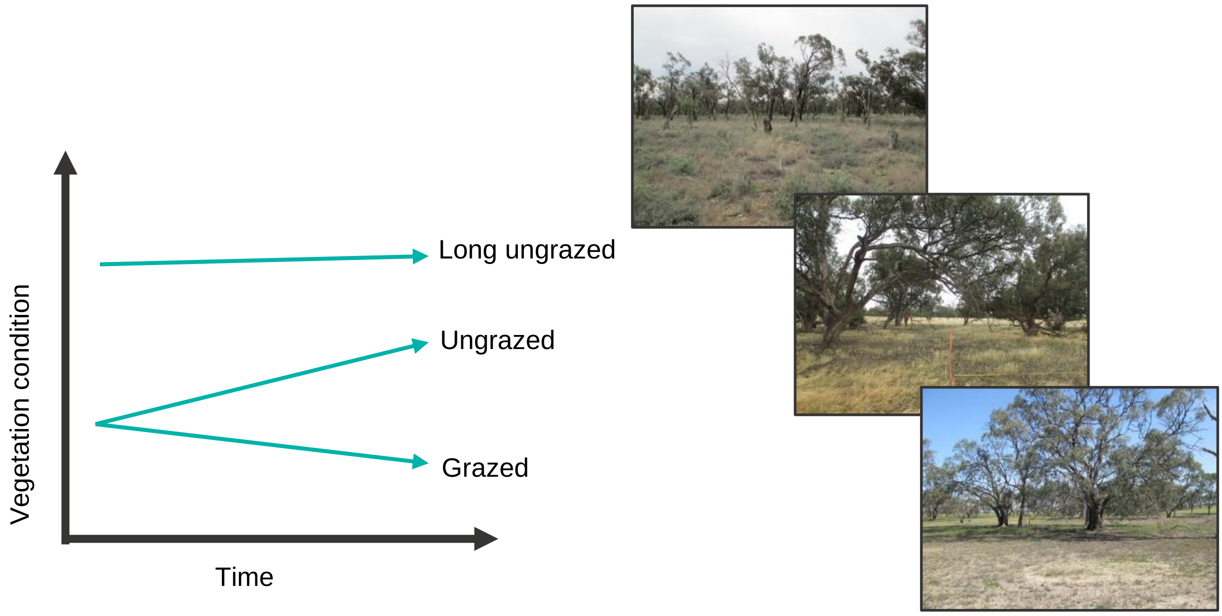



**Figure 2. Expected vegetation response trajectories. Without action, grazed sites will continue to decline.**

For the majority of investment programs an increase in vegetation condition can be defined as:

- an increase in the native component;
- a decrease in the exotic component,
- a decrease in the abundance of bare ground (if appropriate) of a site.

However, most of these vegetation responses occur over longer time periods than the duration of many incentive programs.

Although there are multiple benefits in excluding stock from remnant vegetation (e.g. Lunt et al. 2007a) our current knowledge base does not account for the various recovery trajectories that can take place. Therefore, the effectiveness of stock exclusion fencing has been only rarely quantified (Prober et al. 2009; Prober et al. 2011). The main expectation is that release from grazing pressure can be critical in providing opportunities for trees, shrubs and grasses to flower, set seed and ultimately establish new individuals (i.e. recruitment). However, changes in vegetation condition after stock exclusion vary temporally and spatially depending on remnant starting condition (e.g. plant composition), land use history (e.g. grazing history), vegetation types and environmental variables (e.g. rainfall).

Conceptual models have also been developed to relate management interventions to asset condition (e.g. Lunt et al. 2007a; Duncan and Moxham 2014). These conceptual models form a foundation on which to base our expectations of vegetation responses to stock exclusion. Although numerous conceptual models have been developed to represent the predicted effects of grazing exclusion and recovery of native vegetation (Milchunas et al. 1988; Lunt et al. 2007a; Rumpff et al. 2011), actual vegetation responses vary, and the outcomes are often unclear. For example, livestock grazing can have negative, positive and neutral effects on biodiversity depending on the responses being explored (Schieltz and Rubenstein 2016).

## 1.2 Monitoring investment outcomes

The ability to achieve improved biodiversity outcomes is dependent upon reliable and accurate information to support implementation and adaptive intervention management. Surprisingly, there is little information available that measures success or failure of investment programs on biodiversity outcomes. In particular, the effectiveness of stock exclusion fencing has been only rarely quantified, even though it is a dominant management action in investment programs (Prober et al. 2009; Prober et al. 2011). Addressing this key knowledge gap is essential to evaluate the relationships between management interventions, threat mitigation and asset condition (i.e. native vegetation condition). These relationships and subsequent outcomes form the foundation on which environmental investment programs are based.

A key problem in determining native vegetation outcomes as a result of stock exclusion is the temporal and spatial variation in responses. That is, the success or failure of stock exclusion fencing can often only be confidently determined in the long-term while, in many vegetation types, ecological responses consistent with improvements in vegetation condition may only be evident over multiple decades. Despite this, many monitoring programs which were established as part of regional fencing incentive schemes have run out of funding long before sufficient monitoring data has been collected. Thus, the resulting short-term datasets (< 5 years since grazing) of remnant vegetation condition often correlate more closely with the site history of each remnant rather than whether it has been fenced (Duncan and Moxham 2009) and these datasets do not address appropriate vegetation recovery goals (Lindenmayer and Likens 2009).

Secondly, native vegetation responses vary across a range of spatial scales and environmental gradients (e.g. climatic, ecosystem, productivity), as well as through external drivers of land use change (Morris and Reich 2013; Moxham et al. 2014). Factors include vegetation type, site productivity (e.g. soil type, rainfall), land use history, climatic events (e.g. drought, high rainfall events), and available plant recruitment pathways, which vary greatly between sites and over time. Thus, to adequately determine investment program effectiveness, monitoring programs need to adequately sample enough spatial variation while being committing to long-term monitoring (≥ 10 years).

## 1.3 Project objectives

The ‘Vegetation responses to stock exclusion fencing’ project aims to validate key knowledge gaps regarding vegetation responses to the management intervention of stock exclusion fencing. In particular, it aims to refine the models that are used to evaluate the relationships between management interventions, threat mitigation and native vegetation condition. This was undertaken through a series of meta-analyses that investigated expected responses for a range of native vegetation components (e.g. plant species, functional groups), that are not well understood versus a variety of environmental factors and external drivers.

The outcomes of these analyses will be used to inform on-ground actions and management interventions for future investment programs.

# 2 Project components - meta-analysis

Seven meta-analyses used real data to test and begin validation of the assumptions of models examining the effectiveness of native vegetation management interventions:

1. Meta-analysis of state-wide vegetation change in grassy woodlands (Moxham and Fanson 2018; Figure 3).
2. Meta-analysis of the effects of external drivers, vegetation type and change (Moxham and Fanson 2018).
3. Determining recruitment responses of native woody species to stock exclusion fencing (Moxham et al. 2019a).
4. Quantifying the impact of land management practices on priority remnant vegetation across the dryland Mallee landscape monitoring program: five-year monitoring at a subset of 14 sites (Kenny et al. 2019).
5. Determining broad scale vegetation responses at sites with a short history of stock exclusion (Moxham et al. 2019b).
6. Determining the direction of plant community compositional change after stock exclusion investments (Moxham et al 2019c).
7. Browsing control and progress towards recovery of semi-arid woodlands (Moxham et al 2020).

The outcomes of these analyses are briefly outlined in the below sections. A key focus of this report is to highlight the results in the context of improvements for future management interventions and investment programs. Detailed descriptions of rationale, methods and ecological discussions of findings are not incorporated, but are presented in the individual reports (referenced above).

**Figure 3. Scientists monitoring vegetation change in grassy woodland.**

## 2.1 Meta-analysis of state-wide vegetation change in grassy woodlands

**Background**
This meta-analysis determined the response of woodland understorey vegetation to stock exclusion fencing at a state-wide scale. A time since grazing exclusion chronosequence (0 - 117 years; Figure 4; Moxham and Fanson 2018) was used to explore long-term trends. The analysis focussed on woodlands (predominately with a grassy understorey, although some had a heathy understorey) as this vegetation type was well represented in the majority of investment sites. An increase in woodland condition is defined as a decrease in the exotic component and an increase in the native component. A regional factor (three regions: Northwest, Southwest and Southeast) was incorporated into the analysis to investigate whether changes differed across regional climatic and productivity gradients.

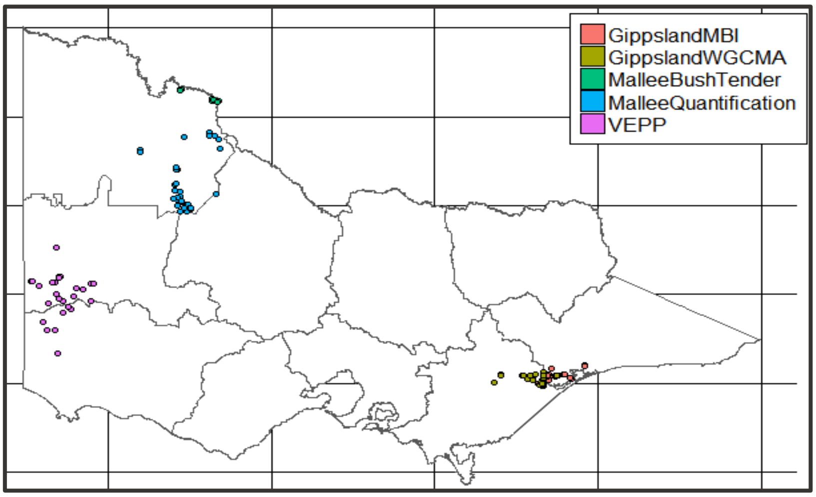



**Figure 4. Location of the five monitoring programs used in this analysis in the northwest, south east and south west of Victoria.**

**Key findings**
Two questions were investigated:

1) What was the understorey vegetation response over time in relation to stock exclusion?
   - Most grassy woodland investment sites either maintained their vegetation condition or improved it (i.e. a decrease in the exotic component and increase in the native component).
   - Most investment sites were in relatively good condition when the investment programs began.

2) Did the understorey vegetation response differ across the state?
   - Vegetation responses differed at the regional scale.
   - Expected vegetation responses differed between regions, reflecting climate and productivity.
     - ➢ Northwest is defined by sandy calcareous soils and relatively low rainfall. In this region, native forb and shrub richness and abundance increased with time since stock exclusion. In contrast, exotic annual graminoid richness and abundance decreased, as did exotic perennial graminoid abundance.
     - ➢ Southwest is defined by the Wimmera plains grey cracking clays and relatively higher rainfall. In this region, native annual forb and graminoid richness increased with time since stock exclusion. Exotic annual responses varied, while forb abundance decreased as time since stock exclusion increased.
     - ➢ Southeast is defined by extensive alluvial systems that typically receive the highest relative rainfall (of the three regions). In this region, native shrub richness and abundance increased with time since stock exclusion fencing. Other native understorey vegetation components were more variable, although native perennial forb richness generally increased. In contrast, native and exotic annual graminoid richness, exotic annual forb and exotic perennial graminoid richness all decreased.

**Recommendations**
- These findings show that state-wide generalisations may lead to misleading conclusions if regional level changes are not considered. Therefore, future monitoring programs at a regional level should adequately capture spatial variation within the project area.

## 2.2 Meta-analysis of the effects of external drivers, vegetation type and change

**Background**

This meta-analysis sought to determine the response of broad understorey vegetation attributes to stock exclusion fencing at a regional level and in relation to a range of external drivers (e.g. starting condition, vegetation type, landscape context, remnant shape, and annual rainfall; Moxham and Fanson 2018).

The analysis investigated short-term vegetation change (0 – 5 years) over a time since grazing exclusion chronosequence (0 - 50 years) in the Northwest region.

**Key findings**

Two questions were investigated:

1) What was the understorey vegetation response over time in relation to stock exclusion fencing?

- Overall investment sites improved in vegetation condition with time since stock exclusion.
- Vegetation responses over time in relation to stock exclusion included: increased native vegetation richness and abundance, decreased exotic vegetation abundance and bare ground.

2) Did the understorey vegetation response differ in relation to external drivers (starting condition, vegetation type, remnant shape, landscape context and rainfall)?

- Vegetation responses were influenced by external drivers:
  - ➢ Effect of vegetation type – vegetation communities responded differently to stock exclusion.
  - ➢ Effect of remnant shape – linear remnants were in poorer condition and may take longer to recover.
  - ➢ Effect of landscape context – remnants with higher native connectivity in the landscape had higher vegetation condition and probability of recovery.
  - ➢ Effect of annual rainfall – influences vegetation recovery and rates of change.
  - ➢ Effect of starting condition – most low condition sites had been recently fenced and will take longer to recover.

**Recommendations**

- Overall, investment sites examined in this analysis showed an improvement in vegetation condition with time since stock exclusion.
- Vegetation responses to time since stock exclusion were influenced by external drivers, some strongly.
- In addition, this analysis identified changes that might be expected in future programs, how these changes are influenced by external drivers, and what improvements might be applied to future programs (Moxham and Fanson 2018). Knowledge of the influence of external drivers (e.g. annual rainfall, vegetation type and landscape context) on vegetation responses assists in predicting the effectiveness of management intervention with respect to different vegetation components.
- These outcomes enable better targeting of future management actions and investment programs.

## 2.3 Determining recruitment responses of native woody species to stock exclusion fencing

**Background**

A state-wide meta-analysis was undertaken to better understand under what circumstances stock exclusion results in increased recruitment of native woody species (e.g. natural regeneration of large shrubs and trees; Figure 5) in investment programs across three Victorian regions – the Northwest, Southwest and Southeast (Moxham et al. 2019a).

**Key findings**

Three main questions were investigated:

1) Where in the landscape is natural woody regeneration occurring?
    - Natural regeneration is occurring across investment sites in all regions. However, the amount of recruitment is low, particularly in the Southwest region.
    - Recruitment probability was highest at sites in the Southeast region.
2) Under what conditions is natural woody regeneration occurring?
    - No influence of substrate (bare ground cover) or canopy cover on recruitment was detected.
3) Over what time period is natural regeneration likely to occur?
    - No effect of the time since stock exclusion fencing was found for recruitment for sites in the Northwest or Southwest. However, in the Southeast, with increasing time since stock exclusion there was an increased probability of large shrub recruitment occurring.

**Recommendations**

From these findings we can draw some conclusions regarding woody species recruitment, future management interventions and investment programs.

- Natural regeneration can be expected to occur across investment sites, but in low abundance.
- The probability of woody species recruitment differs across investment sites and between regions.
- Investment sites in the Southeast, a region of higher rainfall and productivity, are more likely to have natural regeneration in investment sites where stock exclusion fencing has been implemented.
- Many factors influence natural regeneration, most of which were beyond the scope of this analysis. Thus, building site-specific objectives for woody species regeneration into management plans is recommended.

**Figure 5. Grazed (left) and long ungrazed (right) Black Box woodland on private land investment sites.**

## 2.4 Quantifying the impact of land management practices on priority remnant vegetation across the dryland Mallee landscape monitoring program: five-year monitoring at a subset of 14 sites.

Background

This monitoring program was established in 2009. The aim was to fill key knowledge gaps in vegetation responses to stock exclusion and report on investment outcomes. The program has established 82 monitoring sites across the dryland Mallee landscape in three Ecological Vegetation Divisions (Dry Woodland (non-eucalypt), Inland Plains Woodland and Saltbush Mallee) on both private (investment and control (grazed) sites) and public land (reference sites). Sites were established in 2009, 2010 and 2013 as part of investment schemes. Sites were monitored at five-year intervals. Monitoring outcomes will increase our understanding of the response of native vegetation to management interventions across Victoria's landscapes, assisting with the planning and operation of investment programs in the future.

This analysis provides results on short-term vegetation change to enable reporting on investment outcomes (Kenny et al. 2019), using a subset of 14 sites (established between 2013-18; Figure 6), five years since fencing.

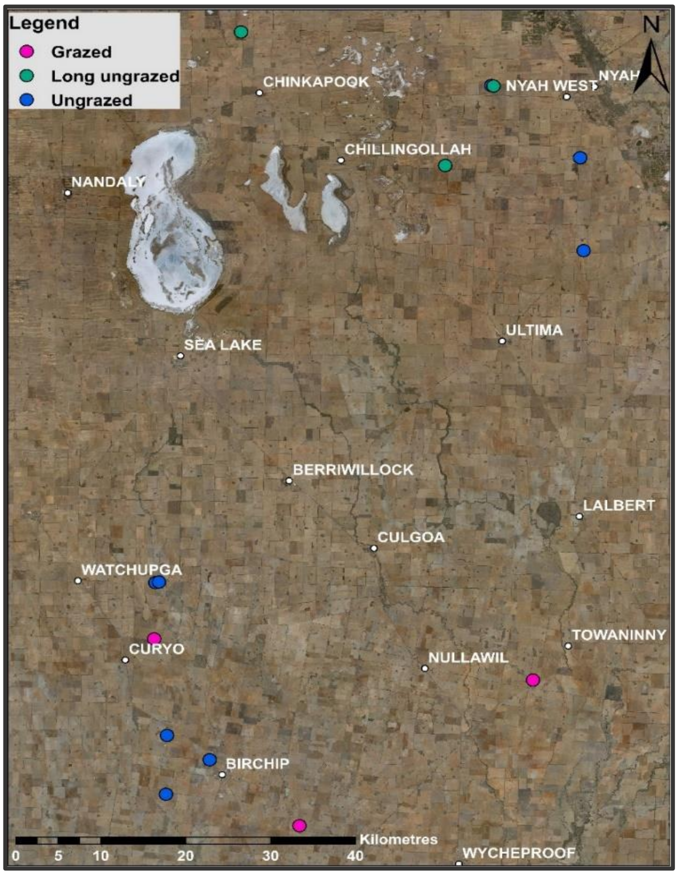



**Figure 6. Site locations across the Mallee landscape.**

**Key findings**

After five years, investment sites generally maintained vegetation condition. However, vegetation condition change over the five-year investment period was variable and complex. Changes were most likely related to the influence of external ecological drivers including starting condition, current and past land use and rainfall, rather than stock exclusion fencing. Key findings were:

- A > 65% decrease in exotic species richness and cover across all sites.
- A 20% decrease in species richness and > 90% decrease in cover of annual species across all sites Decreased annual species cover which was most pronounced on private land investment sites.
- Native shrub cover increased by 75% and was most pronounced on public land reference sites.
- A 50% increase in litter cover across all sites.

**Recommendations**

Stock exclusion fencing has resulted in short-term improvements in native vegetation condition on private land investment sites. However, not all vegetation components improved, and further interventions and/or longer recovery timeframes may be required. It is expected further improvements will occur in the future as natural recovery processes continue. Key recommendations include:

- Site specific management goals for selected vegetation attributes (e.g. native species recruitment) be developed so that management actions can be better targeted in the future.
- Inclusion of annual weed control at investment sites should be considered in years of average or above-average rainfall.
- All sites should be monitored on a five-year basis to document long-term changes in vegetation condition. These sites are due for ten-year monitoring in Spring 2023.

## 2.5 Determining broad scale vegetation responses at sites with a short history of stock exclusion

**Background**

The aim of this subproject was to investigate short-term (5 years) understorey vegetation change at investment sites with low to medium condition where stock was excluded in the last 10 years (Figure 7; Moxham et al. 2019b). Responses in relation to starting condition and vegetation type were also examined.

**Key findings**

Three main questions were investigated:

1) What vegetation response can we expect in remnants within a five-year period?
   - Vegetation condition was maintained over a five-year period once stock was excluded.
   - Some, but not all vegetation response attributes were detected over a five-year period, however the likelihood of detecting change was greater over longer timeframes.
   - Expected versus observed recovery of vegetation attributes were likely to differ in the first five years of investment and were influenced by starting condition, vegetation type and external drivers (rainfall).

2) How does starting condition influence this recovery?
   - Initial site condition differed between vegetation types and influenced vegetation responses.
   - Sites with low starting condition were more likely to change over a five-year period than high condition sites.
   - In low to medium condition sites, exotic annuals were expected to decrease over a five-year period, but this response may also be influenced by vegetation type and annual rainfall.
   - Starting condition was an important consideration when investing in low to medium condition sites.
   - Minimal vegetation change was expected to occur in high condition sites over a five-year period.

3) Do mallee and woodland vegetation types differ in their recovery after stock exclusion fencing?
   - Vegetation types did respond differently to stock exclusion fencing.

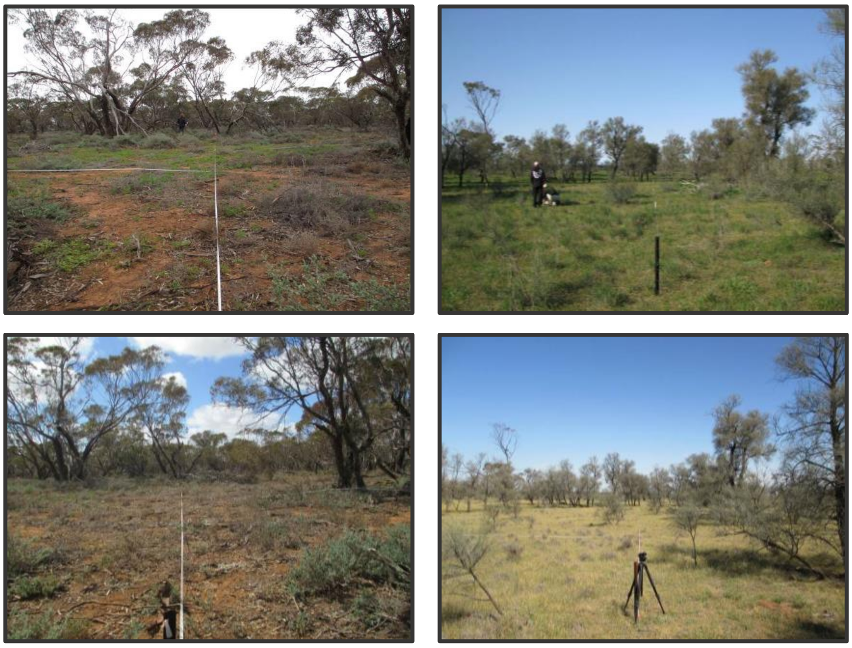


**Figure 7. Mallee and woodland vegetation over a five-year period (top year one – bottom year five).**

**Recommendations**

This analysis provides insights into the role of starting condition, vegetation types and expected versus observed vegetation responses over a five-year investment period. However, some vegetation responses might not be directly attributed to management interventions, and longer time frames may be required to detect responses.

- Ten-year investment programs should be considered in order to detect responses.
- Additional management interventions should be considered to improve vegetation condition within a five-year period (e.g. annual weed control, supplementary planting).

## 2.6 Determining the direction of plant community compositional change after stock exclusion investments

**Background**

This analysis investigated the direction of plant community compositional change (using plant diversity indices), in both Mallee and woodland investment sites, before and five-years after stock exclusion (Moxham et al 2019c).

Currently, it is expected that after a management intervention has been implemented, plant community composition will start to change over time to more resemble a reference community. However, over a five-year investment period the plant community may simply maintain composition (i.e. no change) or change towards a novel plant community. Thus, to enable effective management of native vegetation investments, knowledge of the direction of plant community compositional change is required.

**Key findings**

Two questions were investigated:

1) Does removal of grazing pressure result in increased plant diversity? We predicted species richness (alpha diversity) and species turnover (beta diversity) would increase over the five-year period. Key findings:

- Forb and graminoid species richness declined slightly over the five-year monitoring period, irrespective of origin or vegetation type. However, shrub responses were more varied.
- In contrast, forb beta diversity increased (i.e. sites became more unique or dissimilar) for both Woodland and Mallee sites over the five-year monitoring period.
- Overall, actual site responses and predicted model responses displayed high variability, highlighting that it is difficult to confidently predict species richness responses at investment site over short time periods.
- Forb beta diversity in low condition sites diverged from the high-condition reference sites, with the woodland sites having a stronger response. That is, low condition sites were changing to a novel plant community, and not towards a reference state.

2) Does increasing habitat connectivity (defined by more native vegetation surrounding a site) provide sources of species (e.g. propagules) and hence increase occupancy rates for all lifeforms? Key finding:

- Habitat connectivity was found to increase plant species occupancy rates for woodland forbs and Mallee shrubs.

**Recommendations**

- Landscape connectivity should be considered as an important factor for investment prioritisation.
- The expectation of returning native vegetation to a predefined reference state by stock exclusion alone may need to be re-evaluated.
- Additional management interventions may be required to improve vegetation condition in mallee and woodland vegetation in order to meet management goals.
- The use of species diversity indices as a measure of improvements in vegetation condition should be used in combination with other metrics (e.g. abundance) to fully evaluate investment outcomes.

## 2.7 Browsing control and five-years of vegetation change

**Background**

The semi-arid non-eucalypt woodlands of north-western Victoria are severely degraded after over 200 years of disturbance (e.g. timber harvesting, weed invasion, browsing by native and introduced herbivores). The canopy layer is largely composed of sparsely distributed veteran individuals, with limited natural regeneration.

To improve woodland condition, a long-term restoration program is being implemented which uses population control measures to manage total grazing pressure (browsing by rabbits, goats, kangaroos). However, some key challenges for land managers include implementing recovery actions across a large landscape, climatic factors that influence recovery, and the slow growing nature of these woodlands.

To gain a broad understanding of the recovery trajectory of semi-arid woodlands in relation to browsing control we investigated vegetation change at 120 sites over a five-year period (2012-2017/2018), across three regions in north-western Victoria (north-west and eastern Murray-Sunset, and Hattah-Kulkyne National Parks; Figure 8; Moxham et al 2020).

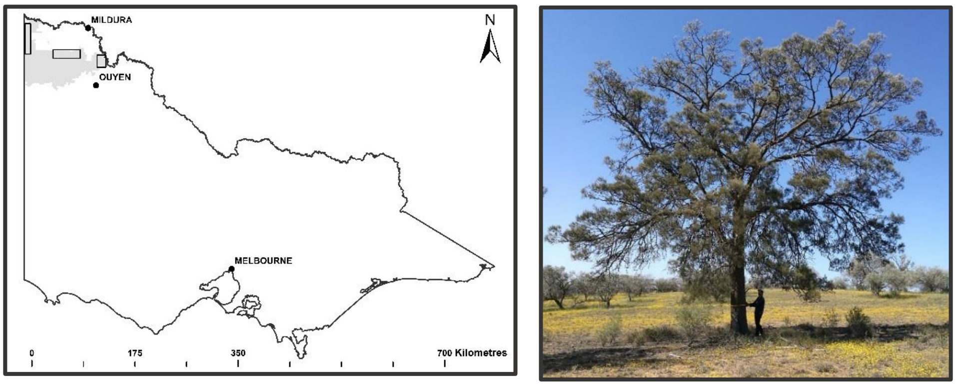



**Figure 8. The three study regions across north-western Victoria (left) and a scientist monitoring a semi-arid woodland with the understorey in flower (right).**

**Key findings**

The current management practice of reduced grazing pressure appears to be maintaining semi-arid woodland condition (Figure 9). Key findings include:

- Positive changes in canopy trees including increased recruitment and no decline in adult health.
- Native understorey plant composition was relatively constant, while an increase in exotics was observed.
- Vegetation responses differed between the sampling regions with the increase in exotics and canopy tree recruitment most pronounced in north-west Murray-Sunset National Park.

**Recommendations**

- The improvements in tree population dynamics suggests that the total grazing management program should be maintained to realise the overall longer-term benefits.
- The small observed increase in recruitment remains a concern and implies that there is more work to do.
- Due to climatic variation, sparse recruitment events and the slow growing nature of semi-arid woodlands, further active revegetation is required. Thus, management in these semi-arid woodlands requires a long-term perspective to ensure sustainability and ongoing monitoring is required to determine the short and long-term impact of the total grazing management program.

**Figure 9. Semi-arid woodland.**

# 3 Decision support framework

## 3.1 Summary of findings

This project has shown that native vegetation investment programs with the management intervention of stock exclusion fencing have generally maintained or improved vegetation condition (Figure 10). Changes in vegetation and ground layer attributes were also influenced by external drivers including annual rainfall, vegetation type, starting condition and landscape context. Thus, when undertaking management interventions to improve native vegetation condition, these external drivers must be considered during the development of management plans and implementation of interventions.

The findings in this report contribute to improving forthcoming monitoring programs by refining future predictions regarding the expected vegetation responses. This will lead to improved regulatory decisions, and investment program outcomes that demonstrate their effectiveness over both the short- and long-term. By improving the efficiency and effectiveness of future monitoring and investment programs, this work directly contributes to Protecting Victoria's Environment - Biodiversity 2037.

***Stock exclusion fencing is a worthwhile management intervention to achieve native vegetation outcomes***

**Figure 10. Fence line contrast between sites where stock have been excluded (left; > 5 years), and stock grazing has been maintained (right). Photo was taken in 2019 on property in the Habitat Tender program.**

## 3.2 Improving native vegetation investment programs

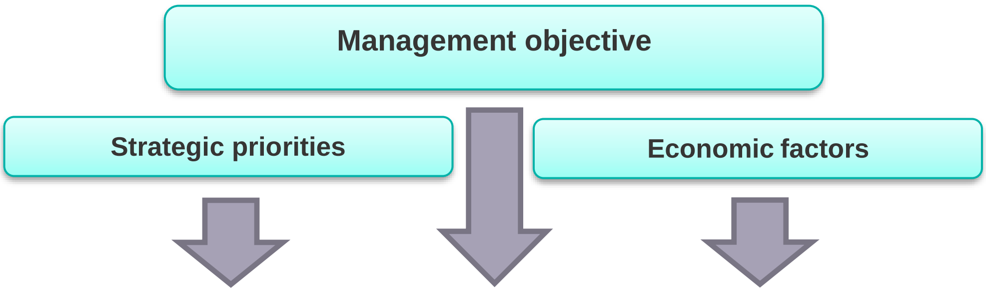
### 3.2.1 Framework for investment priorities

The targeting of native vegetation remnants for investments will depend on the management objective(s). Certain remnants are more likely to benefit from investment (i.e. improved vegetation condition) than others and therefore represent the most value for investment. Priority remnants for investment include:

1) Primary investment remnants: sites that are non-linear (low edge to area ratio), of medium to high condition, have > 10 years stock exclusion and are connected to others in the landscape. These remnants represent the best biological and financial value.
2) Secondary investment remnants: sites with a combination of attributes from points 1 and 3.
3) Tertiary investment remnants: sites that are linear (or have a high edge to area ratio), of low condition, have recent stock exclusion (e.g. < 10 years) and are fragmented in the landscape.

Decisions also depend on remnant availability across the landscape and do not consider a range of variables which are beyond the project scope (e.g. economic factors and strategic priorities). The Strategic management prospects (SMP) project, which is a decision-making platform to advise where actions are of best value, should also be considered.

The selection of remnants for stock exclusion fencing investment should consider a range of site parameters. These parameters can be used to prioritise investments from low to high priority (Figure 11). However, targeting remnants for investment will also depend on the management objective(s). For example, if the objective is to increase fauna habitat, the recommendations here may not be relevant. That is because small and linear remnants in a fragmented landscape may be of disproportionate importance for fauna habitat, and in some cases may be higher priority investments than larger connected remnants. In addition, this prioritisation does not provide a rationale for trade-offs in investment priorities, nor does it take into account other influencing factors and external drivers.




| Factor | Investment Priority: Low | Investment Priority: High |
|---|---|---|
| **Remnant size** | Small | Large |
| **Remnant shape** | Linear | Non-linear |
| **Landscape connectivity** | Fragmented | Connected |
| **Vegetation condition** | Low | High |
| **Vegetation conservation status** | Low | High |
| **Livestock exclusion** | < 10 years | > 10 years |
| **SMP priority** | Low | High |

**Figure 11. Key management drivers (objective, strategic priority and economic drivers) and factors to consider when prioritising site investments (in no particular order) examined in the meta-analysis.**

### 3.2.2 Future investment program considerations

The findings of this project highlight a range of considerations for future investment programs:

- Investment programs of at least ten years duration should be considered. The current practice of five-year programs risks missing the benefit of the management intervention due to the long timeframes over which native vegetation responds to management and the influence of external factors.
- Site selection for investment should depend on the management objectives. For example, if the management objective is to increase fauna habitat in the broader landscape some recommendations outlined here for native vegetation may not be relevant.
- Investment programs should usually prioritise management actions in medium to high condition remnants that are connected to others in the landscape. These remnants represent the best biological and financial value.
- Low condition remnants that are fragmented in the landscape are usually the lowest priority investment and require the highest investment in management actions. However, often these remnants are the only ones remaining in the landscape and provide disproportionate biodiversity values.
- If an increase in vegetation condition is an objective of the investment program (as opposed to maintenance of condition) additional on-ground management actions may be required. For example, if the management aim is to increase woody plant recruitment and this has not occurred after five years of stock exclusion fencing, direct seeding or planting of tube stock should be considered.
- Site-specific management objectives are recommended to maximise investment outcomes.
- The expectation of returning native vegetation to a predefined reference state by stock exclusion fencing alone may need to be re-evaluated. Findings indicate that some sites might change to a novel plant community, rather than towards a reference state. Currently, we lack sufficient long-term data (e.g. > 10 years) to effectively evaluate and predict plant community responses to management interventions, such as stock exclusion.
- Monitoring of native vegetation outcomes should be in and this requires adequate long-term resourcing.

This project addresses key aspects of the relationships between stock exclusion fencing, threat mitigation and native vegetation condition. However, long-term data collection should be incorporated into investment programs in order to effectively evaluate native vegetation responses to stock exclusion fencing and inform adaptive land management decisions.

## 3.3 Expected vegetation responses to stock exclusion

The findings of this project, and published literature, show that the following broad changes in vegetation condition can be expected to occur over time after the removal of stock grazing (the magnitude and rate of change will vary between vegetation types):

- Increased native vegetation abundance, richness and structural integrity.
- Increased native woody species recruitment.
- Decreased exotic vegetation abundance.
- Decreased (reduce excessive cover) bare ground.

However, expected and actual observed changes in vegetation condition may differ and are influenced by a range of factors:

- External factors and remnant history influence vegetation responses to management actions and should be considered when developing management plans and throughout the investment period.
- Observed vegetation responses can differ at a regional scale, representing climate and soil productivity gradients.
- Vegetation responses can be detected over a five-year period for some vegetation attributes, but not others.
- Vegetation starting condition will influence vegetation recovery (and hence program outcomes) and is an important consideration when investing in low to medium condition remnants.
- In low to medium condition sites annual weeds are expected to decrease over a five-year period, but this response may also be influenced by vegetation type and annual rainfall.

- Minimal vegetation change is expected in high condition sites over a five-year period, as these sites are already in a stable condition. It is important to invest in high condition remnants as maintaining condition is a key investment goal.
- Further management actions may be required to improve vegetation condition within a five-year period in order to meet management goals; particularly in low condition sites.
- Natural tree regeneration can be expected to occur, but in low abundance and is dependent on a range of factors (e.g. site condition, rainfall, time since stock exclusion) and responses may be slow.
- The probability of natural tree regeneration differs across investment sites and between regions.

Because vegetation responses are influenced by internal and external drivers, some strongly, considerations for investment programs should include:

- Effect of vegetation type – different vegetation communities respond differently to stock exclusion fencing.
- Effect of remnant shape – linear remnants are often in poorer condition and may take longer to recover.
- Effect of landscape context (nativeness) – remnants that are more connected in the landscape have higher vegetation condition and higher probability of improvement.
- Effect of annual rainfall – influences vegetation recovery and rates of change (particularly drought).
- Effect of starting condition – likely to be more important at recently fenced sites (< 10 years).

## 3.4 Improving management plans and native vegetation outcomes

While stock exclusion fencing has been shown to be an effective management action in vegetation with a long history of livestock grazing, additional management actions may be required to maximise improvements in vegetation condition (as opposed to maintaining condition). It is recommended that management plans should include site-based objectives and targets in relation to management actions and the expected native vegetation recovery time frames. This approach should be particularly considered for short term investments (< 5 years) and low-medium condition sites. Key recommendations include:

- If investments include remnants of low-medium condition, then extra management actions may need to be considered to maximise the chance of positive change in site condition (e.g. annual weed control and/or revegetation).
- Site-specific management objectives for tree regeneration are recommended. This could be passive (e.g. natural regeneration) and/or active (direct seeding, tube stock). Contingency plans may need to be incorporated into management plans.
- Control of annual weeds may need to be incorporated into management plans, depending on annual rainfall and initial starting condition.

# 4 Future directions

## 4.1 Conclusion

This project has shown that native vegetation investment programs employing stock exclusion fencing as the dominant management intervention have generally maintained or improved vegetation condition. This is evident through positive changes in selected vegetation and ground layer attributes. These changes in vegetation condition were also influenced by external drivers such as annual rainfall, vegetation type, starting condition and landscape context. This indicates that when undertaking management interventions to improve native vegetation condition, these external drivers must be considered in the development of management plans and implementation of interventions. Vegetation responses after stock exclusion fencing vary temporally and spatially depending on a range of factors. Thus, responses are likely to be site specific, but generalisations can be inferred. Returning native vegetation to the condition of reference or benchmark sites is difficult and simply removing livestock is unlikely to result in the restoration of plant communities (e.g. Yates et al. 2000; Merriam et al. 2017). Furthermore, vegetation responses may be constrained by ecological or other limits such that additional management interventions may be required.

This project addresses key aspects of the relationships between stock exclusion fencing, threat mitigation and native vegetation condition, thereby improving the potential effectiveness of management interventions and future investment programs. Data and findings from this project directly contribute to:

- Validating expert opinion to refine future Strategic Management Prospects modelling.
- Supporting improved decision making by contributing to state-wide targets and to meeting the goals of Protecting Victoria's Environment – Biodiversity 2037.
- Contributing to achieving cost-effective results by utilising decision support tools in biodiversity planning processes to help achieve and measure against targets.
- Increasing the collecting of targeted data for use in evidence-based decision making.
- Informing on-ground actions and management interventions through an adaptive management framework.

However, scientifically rigorous long-term monitoring data are required to fully evaluate native vegetation responses to stock exclusion fencing. All investment programs, where some form of management intervention is being applied should include a component that explores the outcomes of those investments.

Monitoring is also important for forewarning of impending species declines and/or extinctions, creating triggers for management and quantifying the effectiveness of management practices designed to conserve biodiversity.

## 4.2 Remaining knowledge gaps

This project identified several key knowledge gaps in relation to vegetation responses to stock exclusion. It has refined the models that are used to evaluate a number of the key relationships between management interventions, threat mitigation and native vegetation condition. These outcomes form the basis on which future environmental investment programs are built.

However, more work is required to address these knowledge gaps to enable the determination of outcomes and improvements in management interventions and future investment programs. For instance, the expected responses for a range of plant community parameters (e.g. individual species, woody species, various functional groups) is unknown, over a range of environmental factors, external drivers and management scenarios (and various additional interventions). Further, more predictive models about expected responses, across a range of scenarios are required so that management activities can be implemented to improve vegetation condition over different temporal and spatial scales. This will provide improved knowledge about where and in what circumstances management interventions can be carried out most effectively.

Remaining knowledge gaps and research that can't be addressed by the existing project data are highlighted below and outlined in more detail in the project's Future Directions Report (Moxham 2020).

### 4.2.1 Impediments to filling knowledge gaps

There are two main ongoing issues when undertaking native vegetation research and monitoring, particularly in relation to working on private land. These are maintaining implementation of a robust experimental design; and accounting for the long vegetation recovery time periods and the influence of external drivers, particularly rainfall. Even with adequate resourcing, these issues create challenges in filling the remaining knowledge gaps.

**Experimental design**

Most monitoring programs, particularly those on the private estate, are confounded by variability and uncertainty in the design, and even the most rigorously designed program can lose experimental rigour over time. This project has identified three main design problems that reoccur in Victorian monitoring programs and hamper accurate evaluation of the outcomes of intervention investment programs:

(1) a lack of control or reference sites in the landscape;

(2) change in land tenure leading to the loss of control or treatment sites; and

(3) variation in time since stock exclusion fencing. Although sites are ‘fenced’ at the start of an investment program, sites vary in time since stock exclusion (e.g. 0 - 10 years). This variation in time since stock exclusion is known to influence vegetation starting condition and response trajectories over time and hence investment program evaluation (Moxham and Fanson 2018; Moxham et al 2019a).

**Long time periods and the influence of external drivers**

Vegetation responses that result in condition improvements are often only evident over decades. Despite this, many monitoring programs which were established as part of stock exclusion fencing incentive schemes have run out of funding long before enough monitoring data have been collected to determine success. The resulting short-term data (≤ 5 years since grazing) for remnant vegetation condition often correlate more closely with the site history of each remnant rather than whether or not it has been fenced (Duncan and Moxham 2009), and therefore do not address the vegetation recovery goals of the investment program. This lack of long-term monitoring hinders our ability to determine accurate response trajectories (Lindenmayer and Likens 2009). Secondly, native vegetation responses vary across a range of spatial scales and environmental gradients (e.g. climatic, ecosystem, productivity), as well as external drivers of land use change (Morris and Reich 2013, Moxham wet al. 2014). Determining success is further complicated by the highly variable response of native vegetation remnants and the influence of external drivers. These issues highlight the importance of long-term data sets in the evaluation of investment schemes.

## 4.3 Future research and monitoring

Key areas of future research and monitoring include maintaining long-term data sets and investigating the effectiveness of additional management actions in improving vegetation condition.

### 4.3.1 Long term monitoring of existing sites

A major limitation to assessing the success of stock exclusion fencing is that the ultimate success or failure of an intervention can only be confidently determined in the long-term. In many vegetation types, ecological responses resulting in improvements in vegetation condition may only be evident over decades. As such the importance of long-term data sets cannot be underestimated. It is vital that a selection of existing investment sites that are part of monitoring programs be sampled at five-year intervals to generate a long-term data set.

### 4.3.2 Effectiveness of additional management interventions

The development of further projects to examine the effectiveness of additional management interventions to improve vegetation condition, particularly over a five-year investment period, may be required. Such projects would need to be implemented over different time scales depending on the intervention. For instance, a project examining the effectiveness of crash grazing to control annual weeds would need to be implemented over a minimum three to five-year period to account for community compositional changes and climatic drivers.

Management actions that could be investigated to improve vegetation condition include:

- Improving annual weed control methods (e.g. crash grazing and/or ecological burning)
- Improving woody regeneration outcomes (e.g. Buloke revegetation)
- Investigating cultural and/or ecological burning (e.g. to improve understory condition)

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