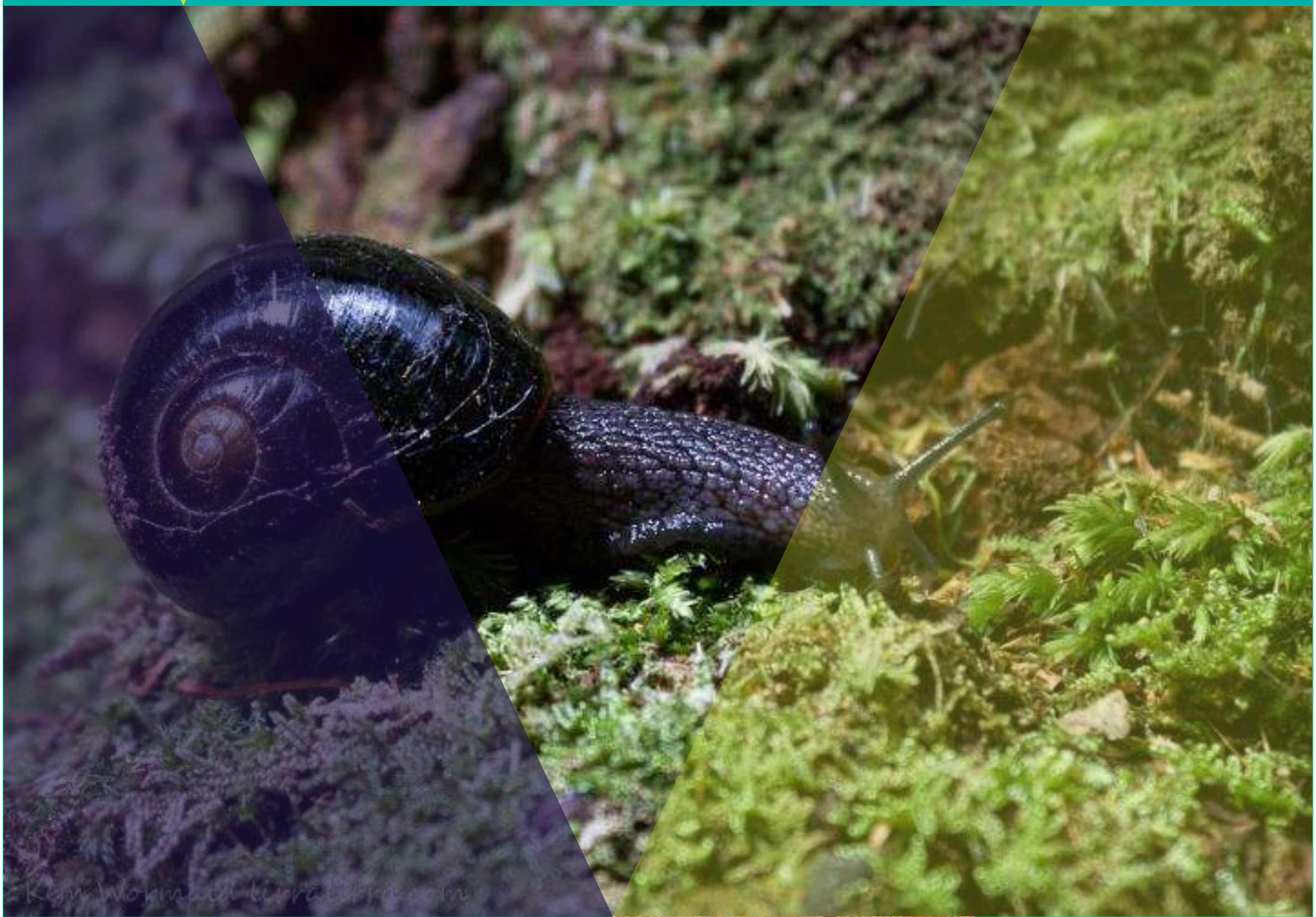
Biodiversity Response and Recovery Supplementary Report:

An assessment to prioritise medium term conservation actions and identify knowledge gaps



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Acknowledgements

We recognise and appreciate the contribution of our taxon leads, those who attended workshops and participated in expert elicitation to make this process possible. A full list of participants can be found in Appendix 2.

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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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Contents

Introduction

Protecting Victoria’s Environment – Biodiversity 2037 (Biodiversity 2037) outlines Victoria’s plan to achieve overall biodiversity improvement over the next 20 years. Within this, the Department of Environment, Land, Water and Planning (DELWP) recognises the importance of being strategic when planning conservation objectives and acknowledges that there is a trade-off between multiple and single species actions. Under the extraordinary influence of climate change new types of interventions and projects that maintain a single species focus will still be needed, particularly for endangered and critically endangered species. These single species management actions will however need to be balanced against landscape-scale multi-species approaches, to maximise the benefit to the most species.

Bushfires play a particularly large role in the health and resilience of Victorian animal and plant species. The 2019-2020 bushfire season represented an episodic threat to species, populations, and individuals. The overwhelming response to recent bushfires has been a recognition that current bushfires are exceptional in both size and impact, and that a changing environment due to climate change will further increase the scale and complexity of managing fire impacts on biodiversity. Multiple large-scale fires combined with an increasing proportion of land that has been burnt multiple times since 2000, has expanded the context in which mitigation efforts for biodiversity needs to be framed. For instance, for certain species and actions, mitigation efforts will need to include options beyond areas directly affected by fire.

An overarching strategic approach to the biodiversity response and recovery from Victoria’s recent bushfire emergency is vital, including the coordination of enacting recommendations and utilising multiple funding sources. The responsibility for delivering actions must be undertaken by relevant land managers and relevant natural resource management organisations, with coordination of the response and recovery (including allocation of funding) and oversight through DELWP. Funding for delivery of response actions may come from different jurisdictions and sources (including external organisations). Biodiversity 2037 ensures that existing processes, such as Biodiversity Response Planning, Forest & Fire Planning, and Regional Catchment Planning, are utilised to progressively engage key stakeholders and support them in recognising and responding to the challenge of climate change impacts, particularly the increased risk of future bushfire.

DELWP has instigated the Biodiversity Bushfire Response and Early Recovery program, which included an initial impact assessment: *Victoria's Bushfire Emergency: Biodiversity Response and Recovery* in January 2020, collaborative workshops with experts and organisations to identify species of concern and potential recovery actions, and a subsequent investment of $17.5 million to support biodiversity recovery. The initial focus of the response was on the most urgent actions (i.e. Phase 1: Immediate and short-term actions - as soon as able to operate in the fire area up to 1 year -) but all timeframes are part of the overall emergency response. This initial assessment was built on in the follow-up report *Victoria’s bushfire emergency: biodiversity response and recovery Version 2* in August 2020, which provided a complete assessment after the 19/20 bushfire event and looks towards future actions (i.e. Phase 2 Medium-term actions - 1-3 years - and Phase 3 Longer-term actions - beyond 3 years -).

The report explored and identified the:

- potential benefits and priorities of post-fire recovery actions inside and outside the bushfire impacted areas, in the medium and long term, and
- priority knowledge gaps that may be influencing the effectiveness of these actions for a range of species across Victoria.

The actions explored through this work contribute to *Theme 5: Maximising long-term resilience across the landscape* through DELWP and other partners and organisations. Theme 5 aims to prioritise and deliver projects (using a range of approaches) for populations of key species, to increase the medium and long-term resilience (i.e. ability to recover) of these species and ecological communities across Victoria. In contrast to immediate actions within the current fire extent, Theme 5 specifically relates to the longer-term, state-wide recovery of species and populations, with a vision of ensuring that populations are healthy and thriving well into the future.

Prioritisation approaches

The level of impact, the range of species affected, the mix of fire effects, other existing threats, and the wide range of relevant actions (both within and beyond the current fire extent), means there are many considerations and candidates when assessing conservation actions. In this context, prioritisation is essential due to limits in available time and resources, and broadly must consider (adopted from Victoria's bushfire emergency: Biodiversity response and recovery, with an updated focus on medium term):

Importance of biodiversity values

- conservation status of a species, including any potential change to this status resulting from bushfire
- relative importance of populations/locations to the overall persistence of a species
- genetic fitness of important populations
- evolutionary distinctiveness of species

Functional state of ecosystems at locations

- existing chronic threats such as invasive species or habitat fragmentation
- historical regimes of disturbance events such as fire, harvesting, droughts, floods etc and impact on habitat functionality and availability (e.g. forest age classes due to previous events; current unburnt areas as immediate refuges)
- dynamic interactions of threats and disturbance events/regimes
- presence and contribution of key functional groups

Suitability and expected outcomes of actions

- relevance and feasibility of actions
- benefit of actions i.e. the difference in expected outcomes with and without action
- relative contribution of expected outcomes from one action/location compared to all other options

Risks to achieving outcomes

- direction and relative influence of future scenarios for disturbance events/regimes and shifting biophysical envelopes, given climate change
- spreading of risk across a range of geographic (*in situ*) and situational (*ex situ*) locations

Cost-effectiveness of actions

- combinations of the above factors need to be weighed against the cost of the relevant actions to enable programs to achieve the best outcomes for the available resources
- costs need to consider initiation, continuation and exit strategies for actions.

These factors must be considered as an integrated set, noting they are not simply additive and sometimes inherent tensions could undermine the overall intent of the program. For example:

- early commitments are advantageous for urgent and important actions, but subsequently there may be insufficient availability of resources for less urgent but also important actions
- the need for consequent actions must be considered e.g. can extracted/captive-bred individuals be returned to the wild and what options/resources are required to enable this? How intensive or invasive is the action?
- contrastingly, committing to a well-scoped but large and long-term project may narrow future options for other projects.

The prioritisation factors described above are listed according to the primary goal of maximising on-ground biodiversity outcomes but are also considered relevant inputs for enabling actions, such as improvements in knowledge and community engagement/participation.

DELWP has datasets and decision-support tools for quantifying and integrating some of these factors for many species and environments. Where these datasets do not cover specific situations (e.g. particular species and location specific threats), these can be considered in a similar manner and compared to the broader datasets. In particular, decision support tools like Strategic Management Prospects and Specific Needs are used by DELWP to assess the benefit and cost-effectiveness of landscape scale and species-specific conservation actions respectively. DELWP is actively applying existing datasets and tools to assess these above factors to prioritise actions.

Prioritising landscape scale actions for multiple species

When considering prioritisation approaches for broad (landscape) scale actions which impact multiple species across a landscape, DELWP utilises Strategic Management Prospects (SMP).

SMP integrates the distribution of approximately 2000 species, the distribution of threats to species, and the benefits and costs of actions designed to address threats. It aims to maximise species persistence in the long-term (with a targets set for 50 years time) in the most complementary and cost-effective manner possible. Through using complementarity as an objective, SMP prioritises actions in areas that add value, in terms of increases to species probability of persistence, to the existing set of areas and actions identified as high priority. This way a broad range of species are represented rather than a subset.

Nineteen management actions have been included in SMP to date and they are considered long-term and sustained investments. It is expected that once an action is adopted, it is sustained for at least 50 years. Therefore, the benefit of an action is assessed as the difference in probability of persistence, in 50 years time, between an action scenario and no-action scenario. This information is combined with estimates of management costs to calculate the cost-effectiveness of actions, as well as, species habitat suitability modelling, to prioritise actions across the state.

Recent analyses of the expert elicited estimates on the benefit of candidate actions identified the most beneficial action for all species and each taxonomic group included in SMP. The taxonomic groups include: amphibians, passerine birds, non-passerine birds, waders, mammals that are not bats, bats, reptiles, monocotyledons, dicotyledons and ferns and friends. As DELWP continually improves SMP; the next version will include aquatic species. Actions that were most commonly identified as high ranking included ceasing timber harvesting, addressing the frequency of fuel reduction burning, control of horses, cats and foxes and managing grazing. These analyses also identified species that were predicted to have the lowest probability of occupancy in 50 years time even under implementation of their most beneficial action. Where the actions included in the SMP appear to be inadequate for some of these species, alternative approaches, such as Special Needs, will be considered. In this way, the Special Needs Analysis presented here is complementary to SMP.

Causal models to determine knowledge gaps

The development of causal models is a key step in the overall Specific Needs process, by narrowing the focus onto relevant factors and potential actions. Casual models are visual diagrams (translated into matrices for comparison and analysis) which describe the major factors within a system (represented as nodes) and the relationships between them (represented as connections or arrows). The systems, in this case, are broad-scale problem response scenarios – for example, the links between different types of threats and actions – which were highlighted as key knowledge gaps during taxon-focused workshops. Examples of problem-response scenarios include the impacts of a drying climate on the food source trees of Mallee birds, or the potential benefits of artificial tree hollows on the persistence of arboreal mammals.

Each problem-response scenario has two diagrams: one representing the “best-case” where there is considered to be a near-complete understanding of the system and the effectiveness of actions, and another representing the “worst-case”, where there is a high degree of uncertainty in both what is known about the system and the results of any actions.

To determine where the greatest uncertainties are in problem-response scenarios, best- and worst-case scenarios are compared by calculating proportional reductions in uncertainty. This is done by first calculating the proportional reduction in uncertainty for each link between nodes (hereafter “link”) with the difference between the best- and worst-case scenarios using the method described in:

Markoczy, L. & Goldberg, J. 1995. A Method for Eliciting and Comparing Causal Maps*, Journal of Management* 21: 305-333

The proportional reduction in uncertainty represents the contribution of a particular link to the overall difference between the best- and worst-case models. This metric is valid for comparisons within a problem-response scenario but cannot be used to compare between scenarios. Comparison between scenarios requires the calculation of another measure, the expected gain from resolving all uncertain elements. A more through explanation of the process is available in:

DELWP 2020. Biodiversity 2037: Manual for the identification and prioritisation of biodiversity actions and knowledge gaps. Department of Environment, Land, Water and Planning. East Melbourne.

The above manual and collation of current causal models are available on the DELWP Knowledge Portal website (Knowledge Portal (environment.vic.gov.au)).

A higher proportional reduction in uncertainty represents a link in the causal model that has greater uncertainty, compared to other links in the model. The tables for each problem-response scenario depict the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted). The highest ranked links might be considered as better candidates for research projects, as they represent the highest reduction in uncertainty. However, this process does not account for other considerations such as cost of knowledge acquisition, the feasibility, and the capacity of researchers to conduct the study.

The purpose of ranking links is to prioritise knowledge gaps and formulate research questions which will resolve the greatest amount of uncertainty. These questions can then be prioritised for investment or shared with interested parties to coordinate complementary knowledge gathering.

Prioritising species-specific actions

Specific Needs is a decision-support tool designed to rank the cost-effectiveness of species-specific and landscape-scale conservation actions within and between species. It allows DELWP to develop and prioritise species-specific actions which will have the greatest benefit in the most effective locations. The approach was developed by the DELWP Biodiversity Division to compliment SMP – a spatially-explicit, landscape-scale approach, which identifies the most effective and efficient management actions to benefit biodiversity across Victoria.

Strategic Management Prospects allows decision-makers to consider and compare between landscape-scale management actions at different locations. Some species, however, need actions beyond the typical landscape-scale conservation actions currently included in SMP. For instance, certain species may require direct interventions at specific locations and novel or unique conservation actions to remain viable into the future.

To fill this gap, the Specific Needs approach was developed, allowing biodiversity managers to bring critical elements of SMP together with information on the benefits and costs of other actions (e.g. genetic rescue), to consider cost-effective conservation actions for any species in a structured and transparent fashion.

Specific Needs can be used to identify, assess, and contrast various management interventions (including bespoke actions) for a target species and/or location, as well as to compare any results with the library of actions and locations held within SMP. Generally, expert elicitation is used to estimate the benefit of management actions, by asking experts to estimate the probability of persistence of a species in 50 years with and without a particular action. In this regard, outputs can be compared both within and across species to consider which management actions would help achieve the greatest benefit to biodiversity state-wide.

To date, Specific Needs has been used to assess the conversation options for a range of endangered and critically endangered species, including the helmeted honeyeater, lowland Leadbeater's possum and the southern population of the eastern bristlebird (available via the linked library.)

The data collected from SMP and Specific Needs has been analysed to calculate benefit metrics, including Change in Suitable Habitat (CSH), which is used by DELWP Biodiversity Division to help guide future actions and the allocation of funding for Biodiversity across the state – both within and outside the 2019-2020 fire area. This data contributes to knowledge of the benefit of different types of management actions. This wealth of information could also be drawn upon during reporting to calculate the relative benefit of implemented actions to biodiversity across the state.

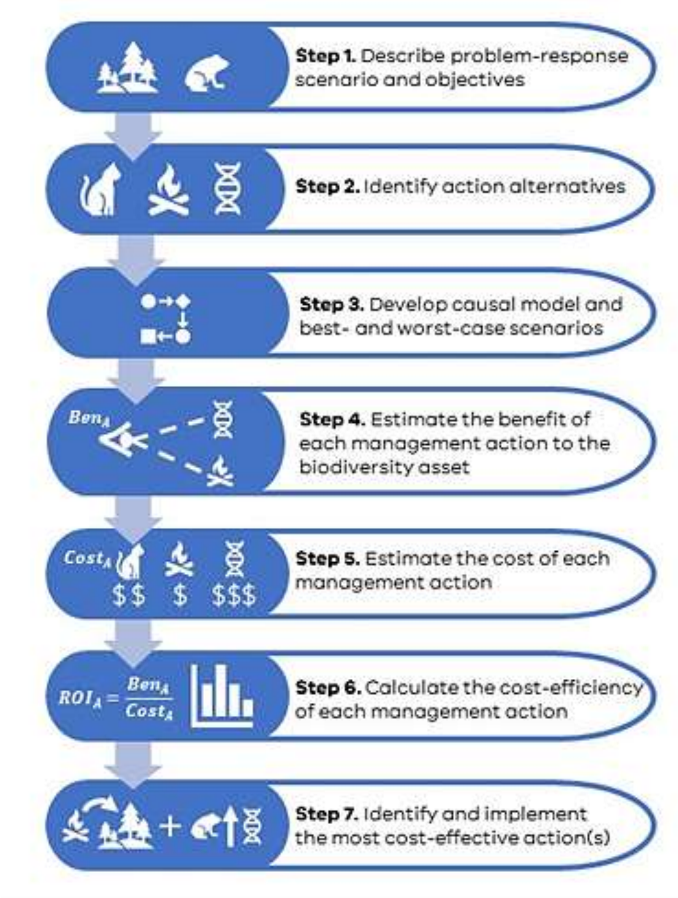

Figure 1. Step-by-step guide of the Specific Needs process. Taxon leads and experts are included in steps 1-4 (covered in this report). DELWP then uses this information for analysis (steps 4-6) and implementation (step 7) at a later stage.

Key components and outputs

The analyses detailed in this report were undertaken for 11 flora and fauna taxon groups. Each taxon group was co-led by an organisation representative from across the state's biodiversity sector (Appendix 2). Leads gathered data through expert elicitation to explore the benefit of species-specific management actions and potential knowledge gaps associated with the specific taxon group.

Prioritisations presented here for species, locations, and actions will be publicly released through this report and the Specific Needs Library App. The app is designed to be constantly updated with the development of this and future specific needs work and partner with other resources (including species reports). It contributes to a pool of DELWP resources which help inform effective and efficient biodiversity management.

Priority actions

Since the release of Victoria's bushfire emergency: Biodiversity response and recovery, DELWP has initiated many broad scale actions with the aim of eliminating threats and strengthening Country, and have moved beyond Phase 1 - Immediate and short-term response and are now in Phase 2 - Medium-term actions (1 – 3 years). Phase 2 will include implementation of priority conservation actions for increased protection and/or management of other areas of habitat or populations that have become more strategically important for key species as a result of the fires.

A compilation of species reconnaissance and post-fire actions will be detailed in Biodiversity Response and Recovery Supplementary Report: Bushfire impacts on species in Victoria.

Some of these short and medium-term actions will be sustained, however others will be phased out for Phase 3 - Longer-term actions (beyond 3 years), as additional actions will be prioritised in the longer term. For example, restoring animals into previously burnt areas, and implementing measures to reduce the occurrence and/or impact of future high severity fires in significant locations.

Actions described in the table below are drawn from the bushfire recovery plan, SMP and *Strengthening Country – integrating the management of ecosystem functions and processes (Version 1- unpublished).*

Hazard	Actions
Increased predation pressure/ effectiveness	Intensified and sustained pest predator control within burnt and adjacent areas
Increased competition and grazing pressure from pest herbivores	Intensified and sustained pest herbivore (e.g. deer, pig, horse, overabundant native) control within burnt and adjacent areas
	Fence local populations for protection from pest herbivore species
	Exclude or manage domestic stock grazing
Increased competition from invasive plants	Intensified and sustained weed control within the current fire extent and adjacent areas
Changes to natural processes Multiple bushfires within 20 years Altered water regimes Human disturbance	Collection of seed and ex situ seed banking for key species
	Spore banking for key fungi species
	Cryodiversity banking
	Reseeding of flora and vegetation communities in key locations
	Active protection of ecological refuges
	Establishment of insurance populations, captive breeding programs
	Ecological burning
Loss of ecological function	Reintroduction / supplementation of apex predators
	Reintroduction / supplementation of digging mammals
	Reintroduction of plants (including ecological replacement)
	Restoring functional habitat (structural components)
Impacts on Traditional Owner ability to connect and heal Country	Healing Country by Traditional Owners through Traditional Knowledge Establishment of Indigenous led positions who liaise with DELWP to share knowledge and heal Country in a way which is self-governing
Small population size effects (inbreeding depression, vulnerability to localised disturbances) Loss of genetic diversity	Population management – wild to wild translocation of critical fauna populations, sanctuaries, captive breeding to support population growth in priority wild populations Genetic rescue
Disease	Protection of key areas without disease
Change in importance of other populations	Protect and manage key populations of species outside fire extent
	Translocation of critical fauna populations
	Creation of safer haven/ sanctuary network
Poorly chosen actions leading to lower outcomes for biodiversity	Strategic approach to learning about the fire impacts and benefits of on-ground response for targeted species and/or threats (including Assessment of biodiversity response effectiveness monitoring options and targeted research to improve the most influential and uncertain actions (Biodiversity 2037 Knowledge Framework)

Amphibians

Introduction

Seven amphibian species were chosen for this analysis based on their location, distribution, and known vulnerability to threats. These species are frogs known to occur in four key Victorian habitat types considered to be of high valuable for the broader taxon group: Riverine (Booroolong Frog and Southern Barred Frog), Lowland Forest of East Gippsland (Large Brown Tree Frog and Giant Burrowing Frog), Lowland (Sloane's Froglet) and Alpine/Sub-alpine/Montane (Baw Baw Frog and Alpine Tree Frog). As such, results are likely to provide generalisable information beneficial to a broader range of amphibian species.

Key knowledge gaps

I. Effect of post-fire landscapes on amphibians

This model examines how conditions and influential factors in amphibian-suitable habitat change post-fire and effect amphibian survivorship and success.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

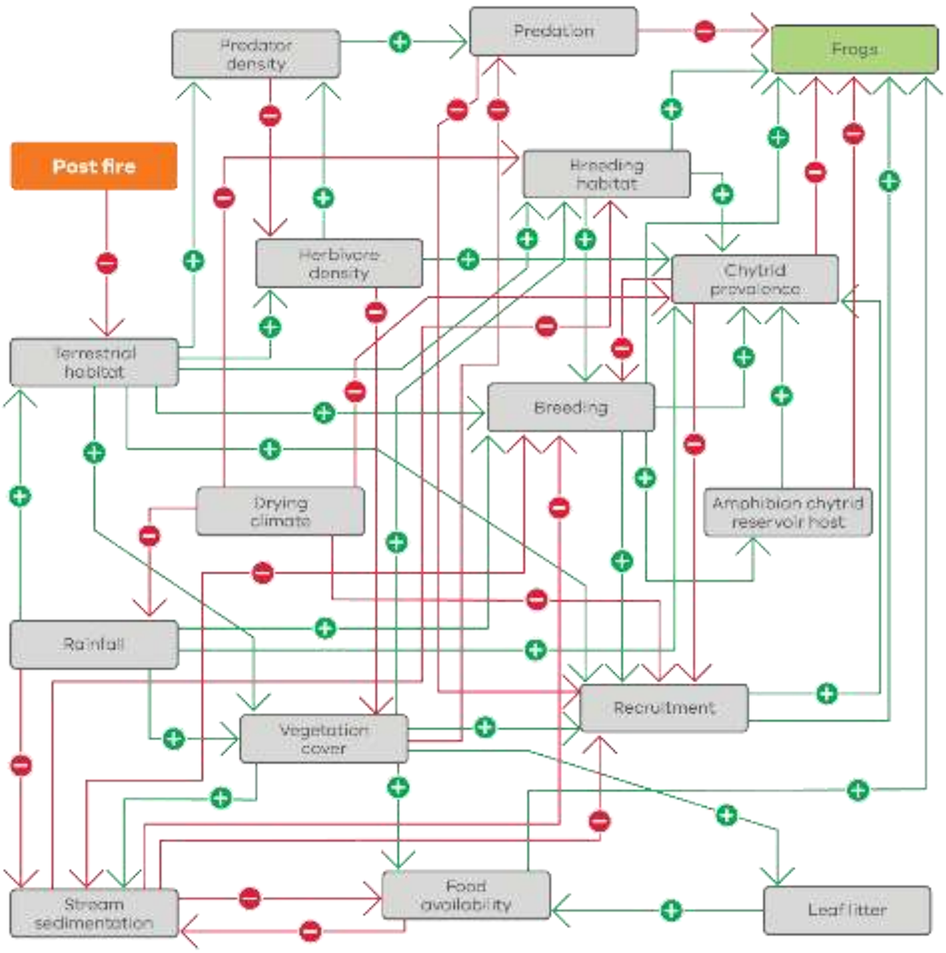

Figure 2. Best case scenario casual model for effect of post-fire on amphibians (frogs). Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

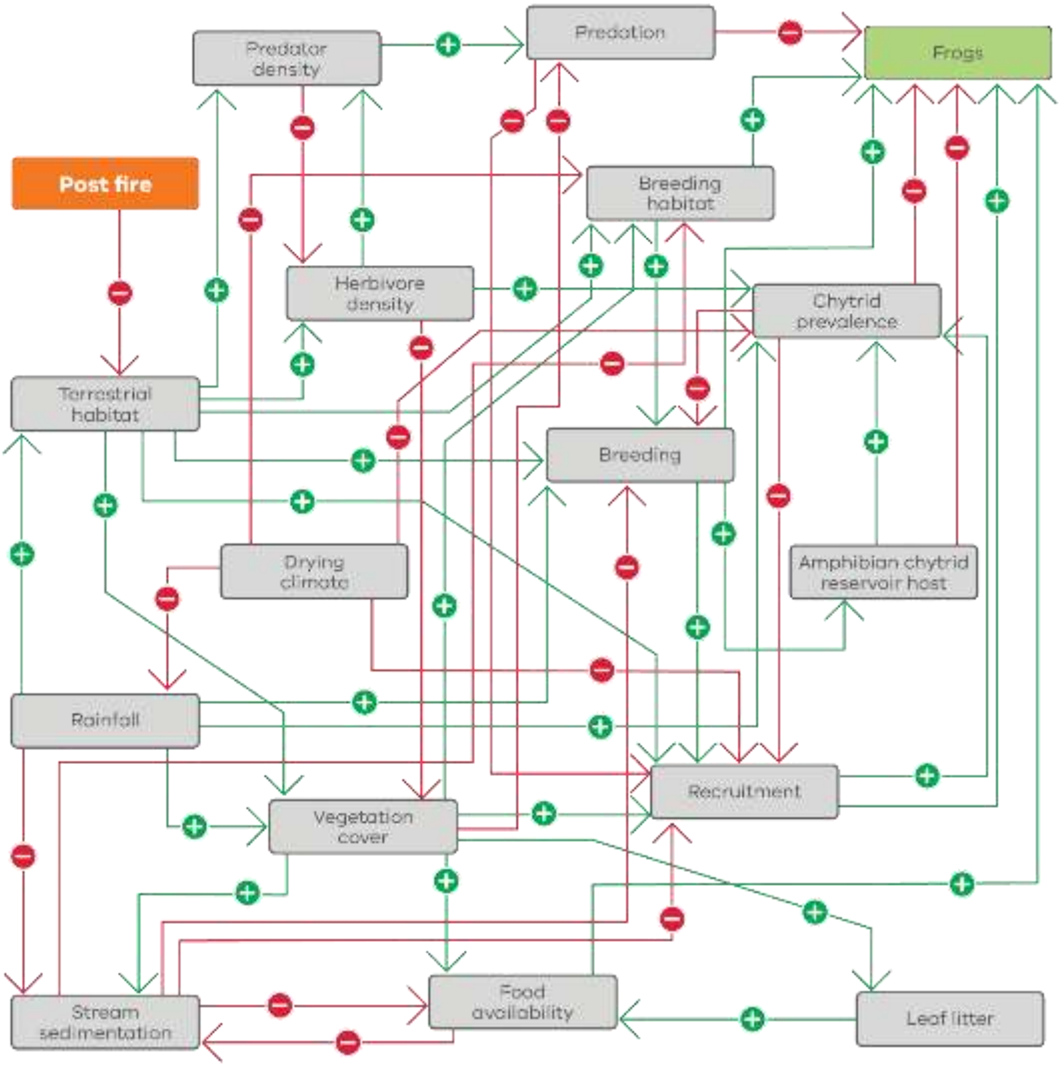

Figure 3. Worst case scenario casual model for effect of post-fire on amphibians (frogs). Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Drying climate	Chytrid prevelence	0.125
1	Deer density	Chytrid prevelence	0.125
1	Horse density	Chytrid prevelence	0.125
1	Drying draining of pools	Chytrid prevelence	0.125
1	Environmental refugia	Chytrid susceptable amphbian species	0.125
1	Control of chytrid	Chytrid prevelence	0.125
1	Chytrid prevelence	Environmental refugia	0.125
1	Breeding habitat	Chytrid susceptable amphbian species	0.125

Figure 4. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for post-fire on amphibians (frogs)

Based on this problem-response scenario, all 8 links above appear to be equal candidates for research projects, as they each represent an equivalent reduction in uncertainty of 0.125. An example of key research question that could be considered from this analysis is “what affect does a drying climate have on Chytrid prevalence”. Links which had no uncertainty (i.e. showed no difference in the best and worst case) are not listed. Here, only links within this model are considered, link comparisons between models can be made in the Knowledge Portal. Once spatial locations and project details such as scale can be determined, further analysis can be completed to consider factors such as species benefit, cost-effectiveness, and existing research.

II. Effect of chytrid control on chytrid susceptible amphibian species

This model examines how control of chytrid fungus (*Batrachochytrium dendrobatidis*) and factors which influence fungus density and spread affect amphibians which are susceptible to chytridiomycosis.

Below is the best- and worst-case models for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

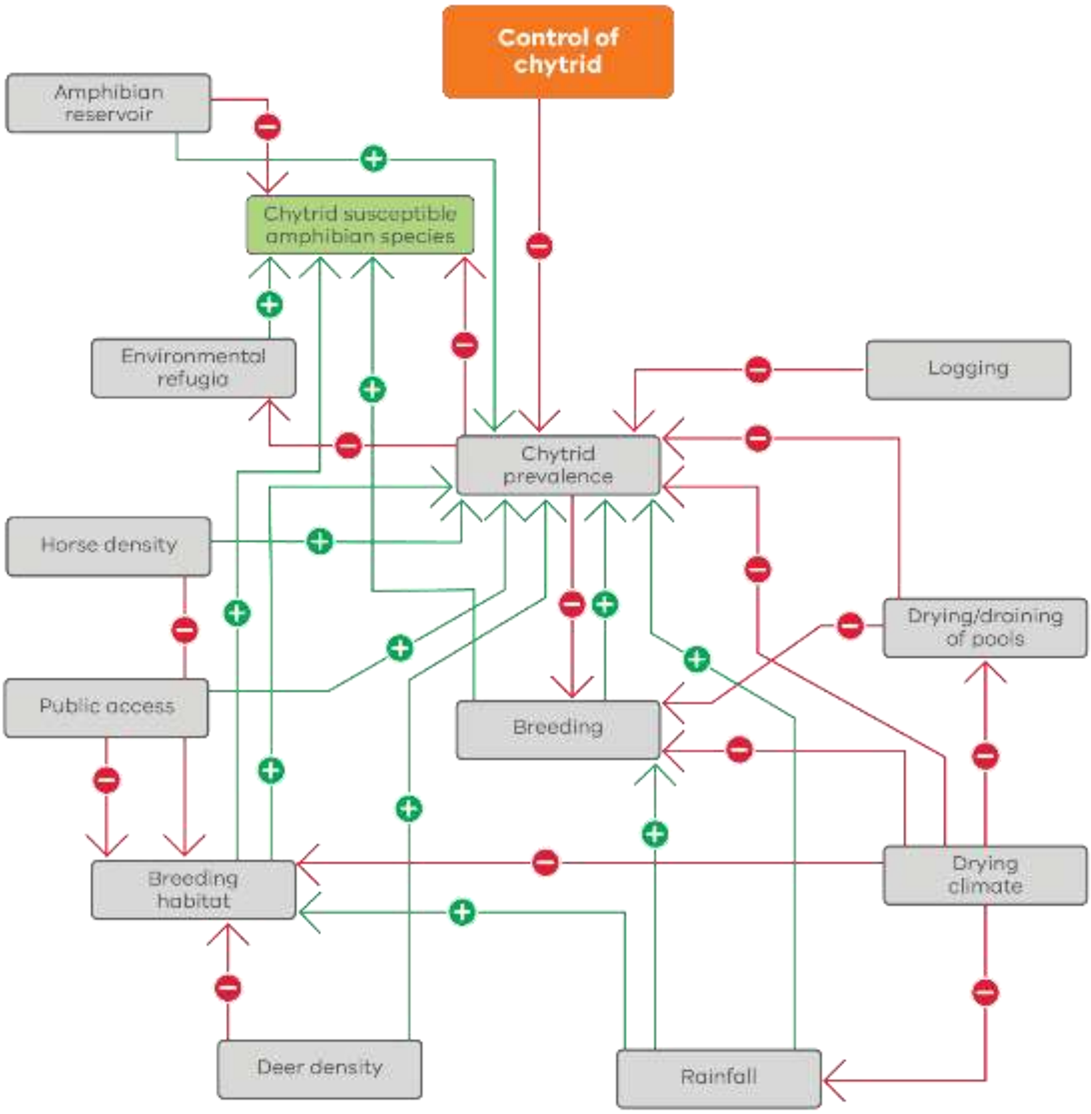

Figure 5. Best case scenario casual model for the effect of chytrid control on chytrid susceptible amphibian species. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

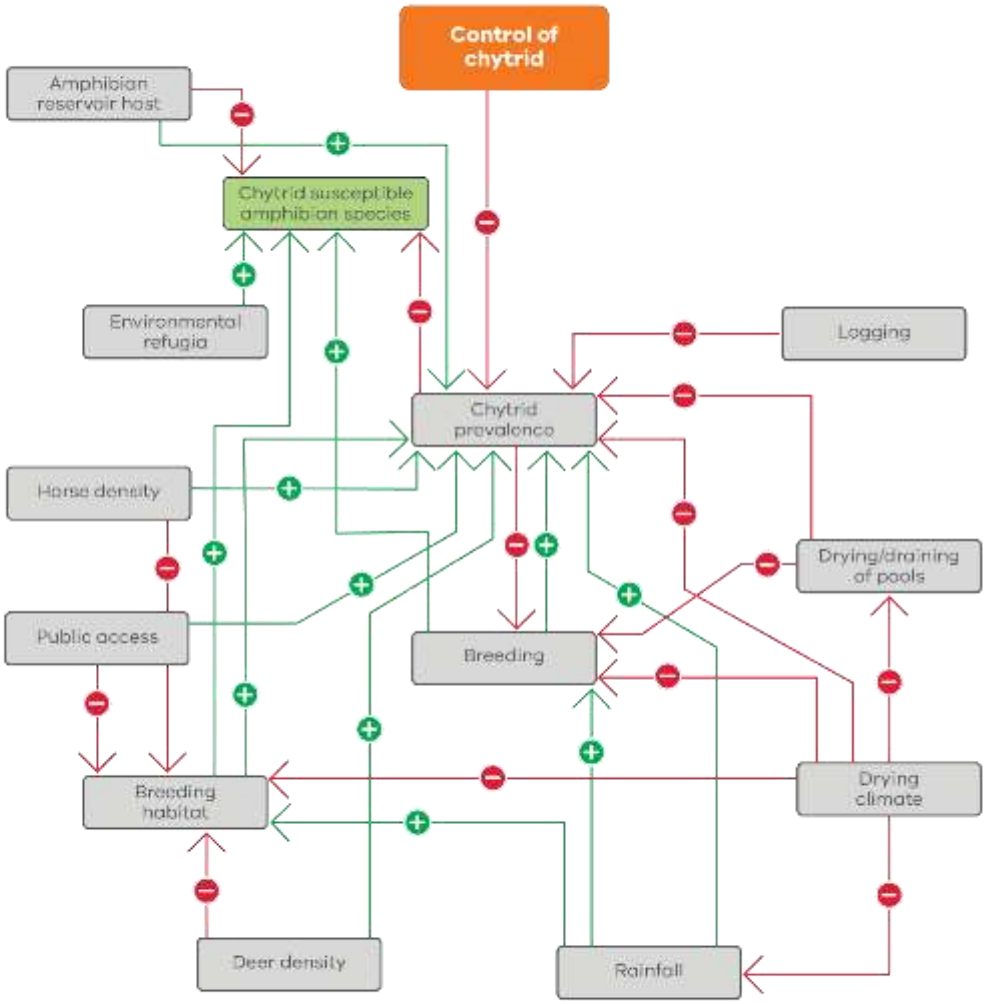

Figure 6. Worst case scenario casual model for the effect of chytrid control on chytrid susceptible amphibian species. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Drying climate	Chytrid prevelence	0.125
1	Deer density	Chytrid prevelence	0.125
1	Horse density	Chytrid prevelence	0.125
1	Drying draining of pools	Chytrid prevelence	0.125
1	Environmental refugia	Chytrid susceptable amphbian species	0.125
1	Control of chytrid	Chytrid prevelence	0.125
1	Chytrid prevelence	Environmental refugia	0.125
1	Breeding habitat	Chytrid susceptable amphbian species	0.125

Figure 7. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for chytrid control on chytrid susceptible amphibian species

Based on this problem-response scenario, all 8 links above appear to be equal candidates for research projects, as they each represent an equivalent reduction in uncertainty of 0.125. Links which had no uncertainty (i.e. showed no difference in the best and worst case) are not listed. Here, only links within this model are considered, link comparisons between models can be made in the Knowledge Portal. Once spatial locations and project details such as scale can be determined, further analysis can be completed to consider factors such as species benefit, cost-effectiveness, and existing research.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 8 and 9) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Booroolong Frog (BF; *Litoria booroolongensis*)

Number of experts: 4

Locations:

Riverine

Current population in Victoria: Two populations in north-eastern Victoria. Actions could occur at one key site in suitable occupied habitat and suitable unoccupied habitat.

#	Actions:	
	No Action	No management of wild populations.
1	Conservation breeding program (CBP)	Establish captive insurance population to breed BF for release (annually n=500). CBP is critical to bridge biological knowledge gaps needed to establish a successful amphibian recovery program. Following establishment of CBP experimentally release BF at key site, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
2	Introduced predatory fish management	Working with Victorian angling community and other stakeholders remove non-native predatory fish at a key site. Following removal of predatory fish use captive bred BF to supplement existing population, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques. Continue to monitor and manage introduced predatory fish population and conduct active removal when required.
3	Species specific chytrid research	Conduct chytrid research to investigate BF immunity. Assuming immunity is identified embed results into conservation breeding program and produce chytrid resistant BF for release at key site. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
4	Develop assisted reproductive techniques (ART)	Using ART selectively breed BF to enhance captive breeding, maximize genetic diversity and potentially selectively breed for chytrid resistance. Embed into conservation breeding program to produce stock for release at key site. Release and monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Population Augmentation and Genetic Rescue	Translocate captive bred animals or wild produced animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
6	Habitat restoration/manipulation	Use manual techniques to improve the habitat quality at key site. This may include construction and maintenance of natural or artificial breeding ponds that promote larval development through to metamorphosis. Following habitat restoration use captive bred BF to populate/supplement habitat, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
7	Weed management	Manage weeds along streams of key site.
8	Landholder engagement	Provide training and engagement opportunities for landholders regarding appropriate management of BF breeding and non-breeding habitat
9	Populations Re-establishment	Translocate captive bred animals or wild produced animals to extirpated BF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on BF at a site are low or can be reduced.
10	Population Establishment via Experimental Release	Translocate captive bred animals or wild produced animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new BF populations at new sites where the impacts of one or more threats on BF are low or can be reduced.

Based on expert assessment the benefit of each action at each location for this species is as follows:

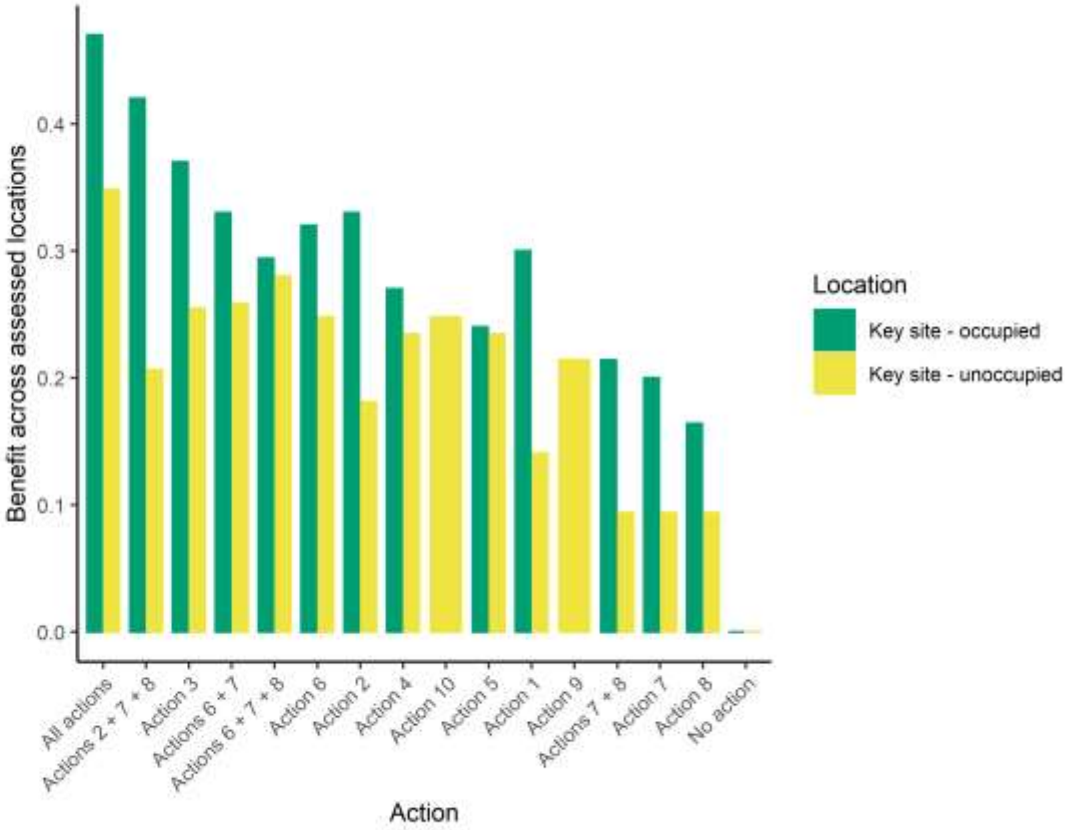

Figure 8. Benefit of each action/location combination to the Booroolong Frog overall persistence probability across all assessed locations.

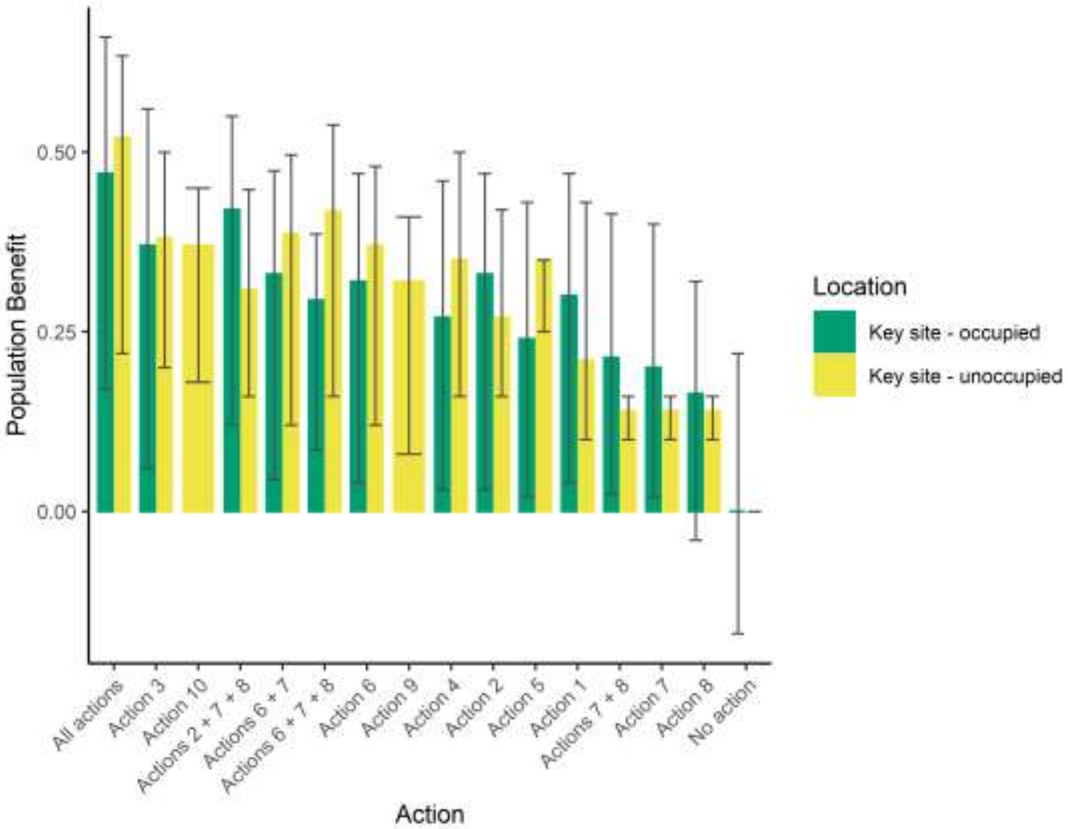

Figure 9. Mean change in Booroolong Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Aside from all actions, when considering benefit across all assessed locations, the most beneficial actions are a combination of introduced predatory fish management, weed management along streams and landholder engagement around appropriate management of Booroolong Frog breeding and non-breeding habitat. However, when assessing mean benefit at each site, chytrid research to investigate Booroolong Frog immunity appears to be the most beneficial. If immunity were able to be instilled through a breeding program, this would certainly be of overwhelming benefit to the entire population.

Species: Southern Barred Frog (SBF; *Mixophyes balbus*)

Number of experts: 5

Locations:

Riverine

Current population in Victoria: North-eastern Victoria, not observed since 1983. Assuming the species no longer occurs in Victoria and that founder stock would be sourced from the Sydney basin ESU. Actions could occur at one key site in suitable historically occupied habitat and suitable habitat outside of historical distribution.

#	Actions:	
	No Action	No management of wild populations.
1	Conservation breeding program (CBP)	Establish captive insurance population to breed SBF for release (annually n=500). Following establishment of CBP experimentally release SBF at key site, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
2	Populations Re-establishment	Translocate captive bred animals or wild produced animals to extirpated SBF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on SBF at a site are low or can be reduced.
3	Introduced predatory fish management	Working with Victorian angling community and other stakeholders remove non-native predatory fish at a key site. Following removal of predatory fish use captive bred SBF to introduce to key site, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques. Continue to monitor and manage introduced predatory fish population and conduct active removal when required.
4	Species specific chytrid research	Conduct chytrid research to investigate SBF immunity. Assuming immunity is identified embed results into conservation breeding program and produce chytrid resistant SBF for release at key site. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Population Establishment via Experimental Release	Translocate captive bred animals or wild produced animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new SBF populations at new sites where the impacts of one or more threats on SBF are low or can be reduced.
6	Habitat creation/restoration/manipulation	Use manual techniques to improve the quality and permanence of breeding habitat at key site/s. This may include construction and maintenance of natural breeding ponds to prevent drying or artificial breeding ponds that promote larval development through to metamorphosis.
7	Planned burning	Mapping key site/s (current DELWP project and BRATS report) to ensure planned burning does not negatively impact important habitat.
8	Population Augmentation and Genetic Rescue	Translocate captive bred animals or wild produced animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.

Based on expert assessment the benefit of each action at each location for this species is as follows:

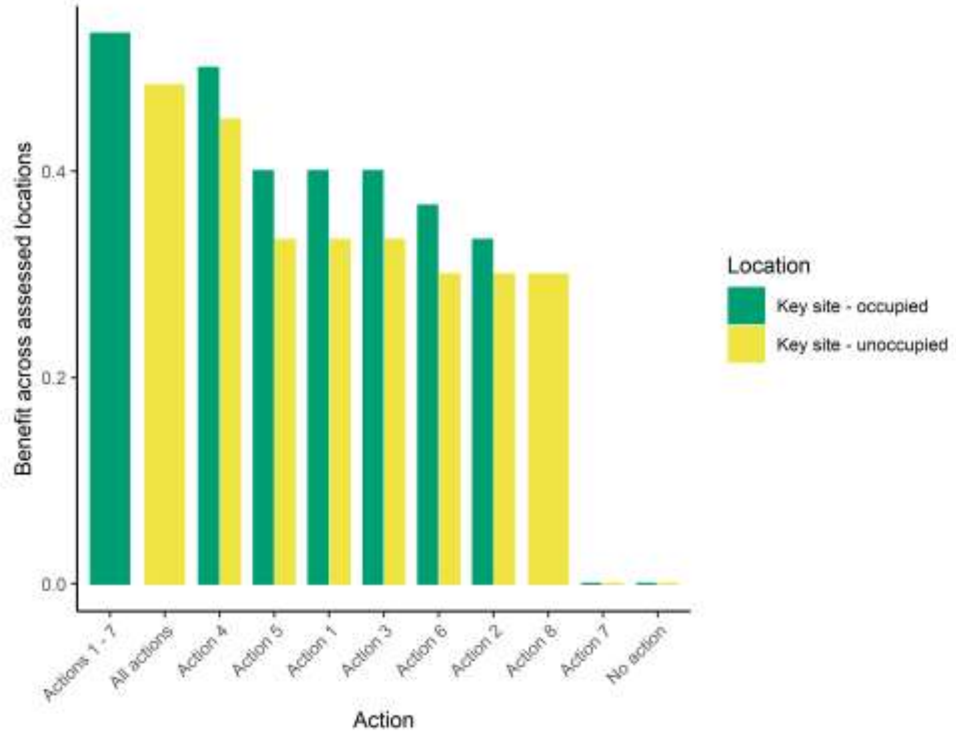

Figure 10. Benefit of each action/location combination to the Southern Barred Frog overall persistence probability across all assessed locations.

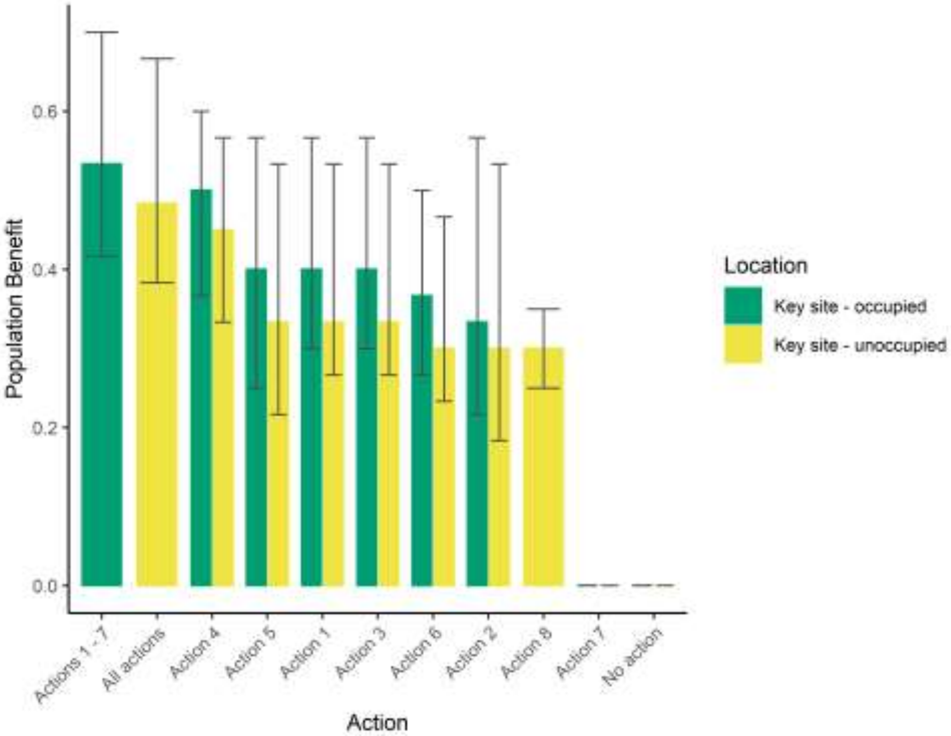

Figure 11. Mean change in Southern Barred Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

For this species, both measures reflect the same preference for actions. All (or all excluding population augmentation and genetic rescue) are deemed the most beneficial, but closely followed by species-specific chytrid research. As with the Booroolong Frog, if immunity were able to be instilled through a breeding program, this action would certainly be of overwhelming benefit to the entire population of Southern Barred frogs.

Species: Large Brown Tree Frog (LBTF; *Litoria littlejohni*)

Number of experts: 5

Locations:

Lowland Forest (East Gippsland)

Current population in Victoria: Rare in Victoria, known from approximately 35 sites post 2000 in East Gippsland. Actions could occur at one key site in suitable occupied habitat and suitable unoccupied habitat.

#	Actions:	
	No Action	No management of wild populations.
1	Conservation breeding program (CBP)	Establish captive insurance population to breed LBTF for release (annually n=500). CBP is critical to bridge biological knowledge gaps needed to establish a successful amphibian recovery program. Following establishment of CBP experimentally release LBTF at key site, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
2	Gene mixing	Analyse genetic structure of extant populations and determine if gene mixing will improve wild genetic structure. Embed into CBP and utilise captive bred stock for release to key site, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
3	Species specific chytrid research	Conduct research to investigate LBTF chytrid susceptibility and immunity. Assuming immunity can be identified embed results into CBP and produce LBTF for release at key site/s. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
4	Develop assisted reproductive techniques (ART)	Using ART selectively breed LBTF to enhance captive breeding, maximize genetic diversity and potentially selectively breed for chytrid resistance. Embed into conservation breeding program to produce stock for release at key site. Release and monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Habitat creation/restoration/manipulation	Use manual techniques to improve the quality and permanence of breeding habitat at key site/s. This may include construction and maintenance of natural or artificial breeding ponds that promote larval development through to metamorphosis.
6	Protection of breeding sites	Fence key breeding ponds to protect from feral herbivores, predators, logging activity and quarantined from CFA use.
7	Special protection zone (SPZ)	Establish SPZ around key site/s to protect from current and planned logging activity.
8	Planned burning	Mapping key site/s (current DELWP project and BRATS report) to ensure planned burning does not negatively impact important habitat.
9	Population Augmentation and Genetic Rescue	Translocate captive bred animals or wild produced animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
10	Populations Re-establishment	Translocate captive bred animals or wild produced animals to extirpated LBTF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on LBTF at a site are low or can be reduced.
11	Population Establishment via Experimental Release	Translocate captive bred animals or wild produced animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new LBTF populations at new sites where the impacts of one or more threats on LBTF are low or can be reduced.

Based on expert assessment the benefit of each action at each location for this species is as follows:

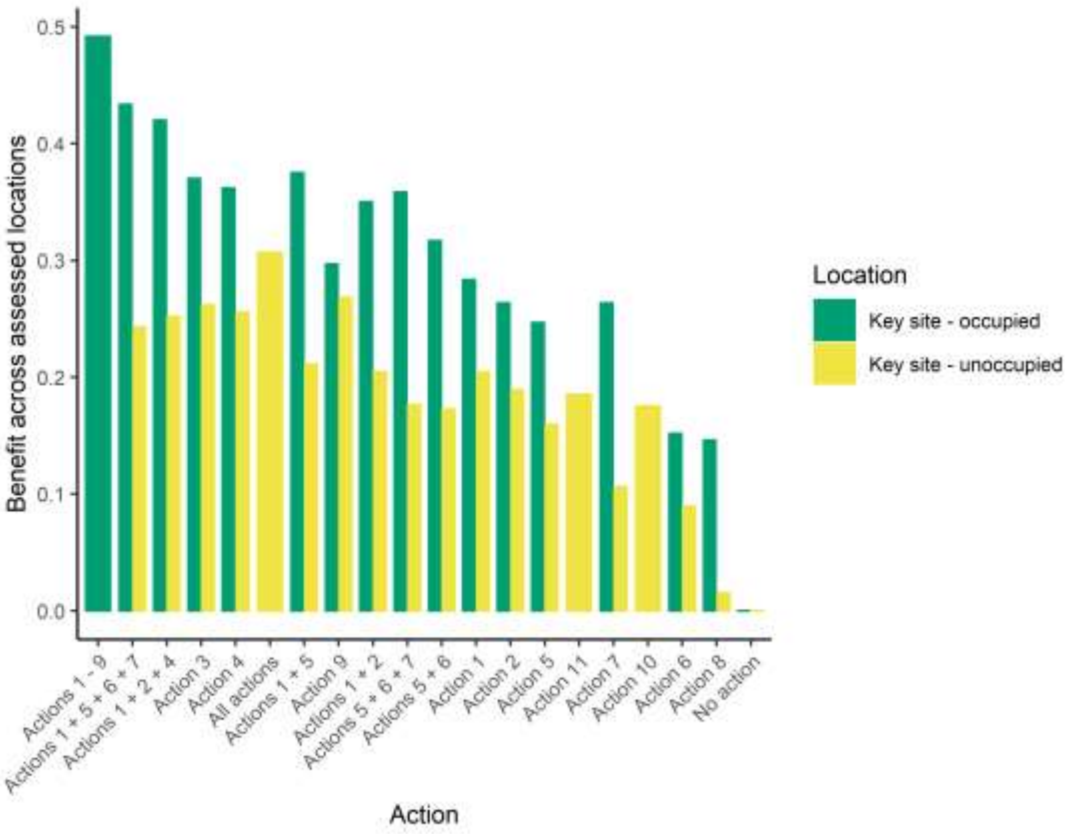

Figure 12. Benefit of each action/location combination to the Large Brown Tree Frog overall persistence probability across all assessed locations.

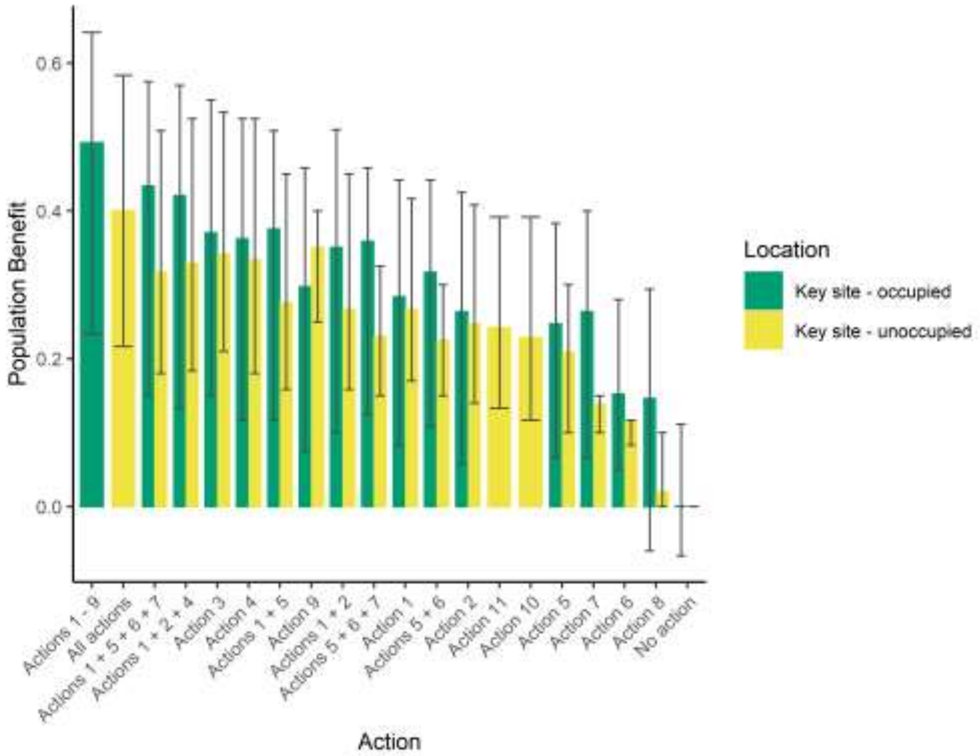

Figure 13. Mean change in Large Brown Tree Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Experts determined that there are many potential actions available for the Large Brown Tree Frog which would result in an improved probability of persistence. While a collection of actions was found to be the most beneficial, the two highest ranked actions under both benefit measures were species-specific chytrid research and developing assisted reproductive techniques. In both cases, these actions aim to improve genetic diversity and immunity to chytrid within Victorian populations, promoting resilience by targeting breeding and release at key sites.

Species: Giant Burrowing Frog (GBF; *Heleioporus australiacus*)

Number of experts: 5

Locations:

Lowland Forest (East Gippsland)

Current population in Victoria: Rare in Victoria, known only from 41 records, currently only one known breeding population. Actions could occur at one key site in suitable occupied habitat and suitable unoccupied habitat.

#	Actions:	
	No Action	No management of wild populations.
1	Conservation breeding program (CBP)	Establish captive insurance population to breed GBF for release (annually n=500). CBP is critical to bridge biological knowledge gaps needed to establish a successful amphibian recovery program. Following establishment of CBP experimentally release GBF at key site, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
2	Gene mixing	Analyse genetic structure of extant populations and determine if gene mixing will improve wild genetic structure. Embed into CBP and utilise captive bred stock for release to key site/s, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
3	Species specific chytrid research	Conduct research to investigate GBF chytrid susceptibility and immunity. Assuming immunity can be identified embed results into conservation breeding program and produce GBF for release at key site/s. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
4	Develop assisted reproductive techniques (ART)	Using ART selectively breed GBF to enhance captive breeding, maximize genetic diversity and potentially selectively breed for chytrid resistance. Embed into conservation breeding program to produce stock for release at key site. Release and monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Habitat creation/restoration/manipulation	Use manual techniques to improve the quality and permanence of breeding habitat at key site/s. This may include construction and maintenance of natural breeding ponds to prevent drying or artificial breeding ponds that promote larval development through to metamorphosis.
6	Special protection zone (SPZ)	Establish SPZ around key site/s to protect from current and planned logging activity or encroachment from agricultural development, including protection of head water catchments.
7	Planned burning	Mapping key site/s (current DELWP project and BRATS report) to ensure planned burning does not negatively impact important habitat.
8	Population Augmentation and Genetic Rescue	Translocate captive bred animals or wild produced animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
9	Populations Re-establishment	Translocate captive bred animals or wild produced animals to extirpated GBF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on GBF at a site are low or can be reduced.
10	Population Establishment via Experimental Release	Translocate captive bred animals or wild produced animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new GBF populations at new sites where the impacts of one or more threats on GBF are low or can be reduced.

Based on expert assessment the benefit of each action at each location for this species is as follows:

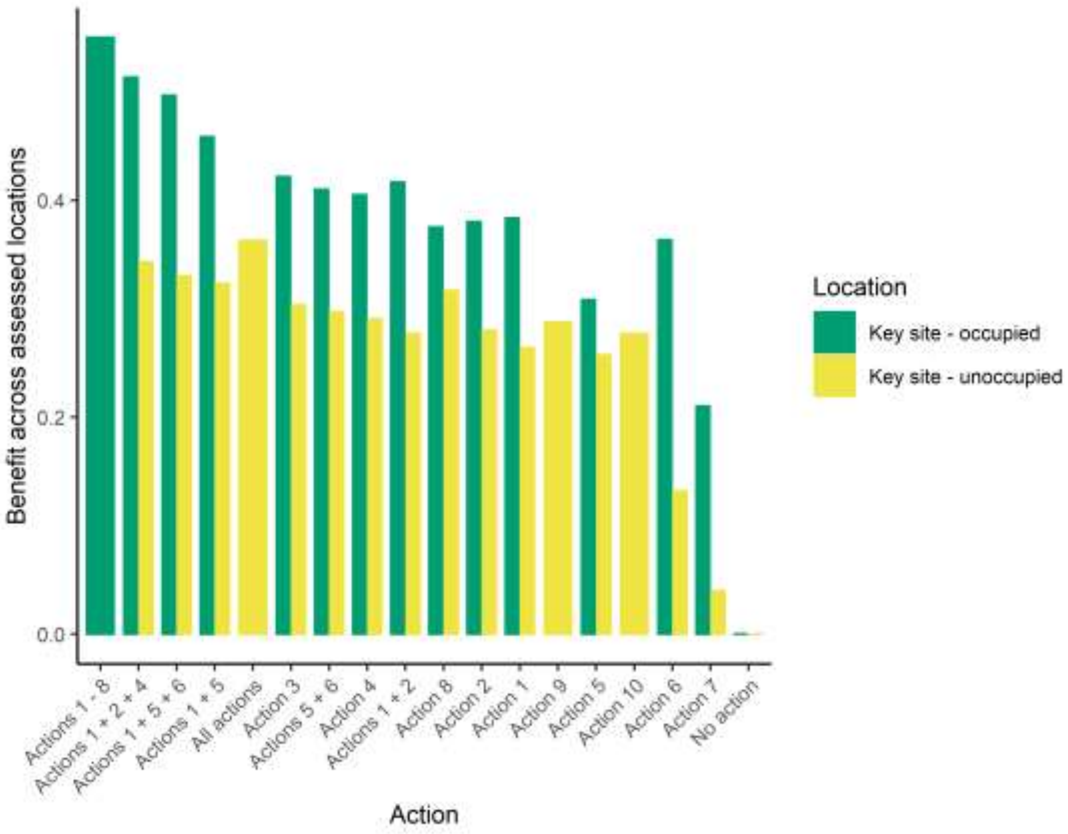

Figure 14. Benefit of each action/location combination to the Giant Burrowing Frog overall persistence probability across all assessed locations.

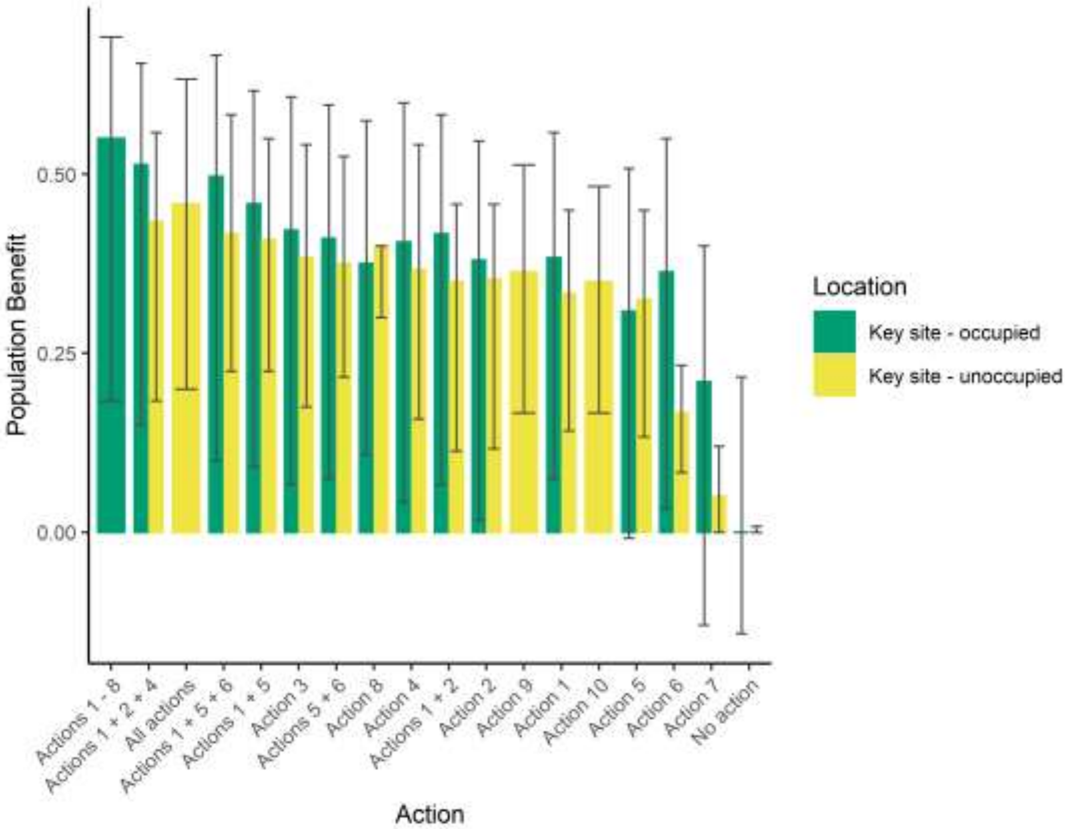

Figure 15. Mean change in Giant Burrowing Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Experts determined that there are many potential actions available for the Giant Burrowing Frog which would result in an improved probability of persistence. While a collection of actions was found to be the most beneficial, the highest ranked actions under both benefit measures were a conservation breeding program and habitat creation, restoration and manipulation to improve the quality and permanence of breeding habitat at key site. In both cases, these actions aim to improve frog numbers, genetic diversity, and resilience by targeting and supplementing key breeding sites. Habitat works (action 5) are effective only when the area is then protected from logging and agricultural development, including protection of headwater catchments, through a special protection zone.

Species: Sloane's Froglet (SF; *Crinia sloanei*)

Number of experts: 4

Locations:

Lowland

Current population in Victoria: Rare in Victoria, known to occur from Echuca to Wodonga and south to Nagambie. Actions could occur at one key site in suitable occupied habitat and suitable unoccupied habitat.

#	Actions:	
	No Action	No management of wild populations.
1	Population Augmentation and Genetic Rescue	Translocate wild produced to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
2	Habitat restoration/manipulation	Use manual techniques to improve the quality at key sites. This may include construction of new artificially created habitat as well as maintenance of water bodies during prolonged drought. Following habitat restoration translocate wild SF to populate/supplement habitat, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
3	Protection of breeding sites	Fence key breeding ponds to protect from herbivores, predators and public activity.
4	Habitat protection zone	Establish habitat protection zone around key site/s to protect from urban and per-urban development including protection of catchment area from agricultural leaching.
5	Landholder engagement	Provide training and engagement opportunities for landholders regarding appropriate management of BF breeding and non-breeding habitat
6	Populations Re-establishment	Translocate wild animals to extirpated SF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on SF at a site are low or can be reduced.
7	Population Establishment via Experimental Release	Translocate wild animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new SF populations at new sites where the impacts of one or more threats on SF are low or can be reduced.

Based on expert assessment the benefit of each action at each location for this species is as follows:

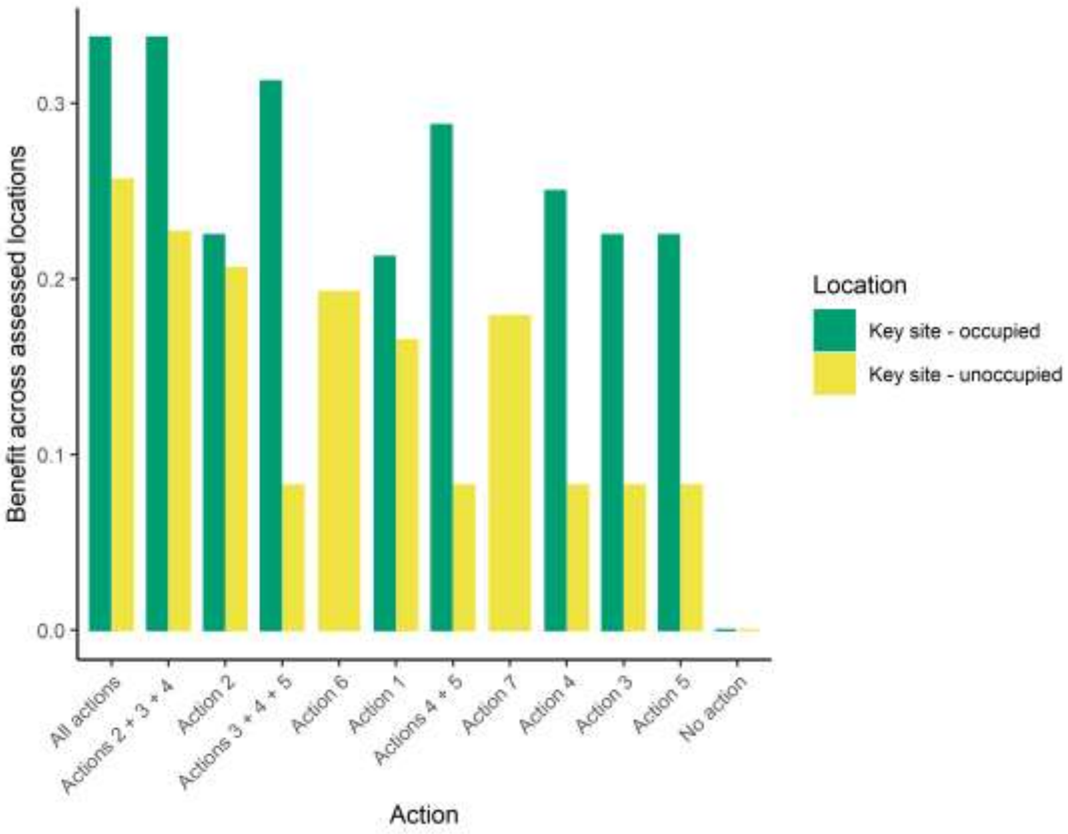

Figure 16. Benefit of each action/location combination to the Sloane's Froglet overall persistence probability across all assessed locations.

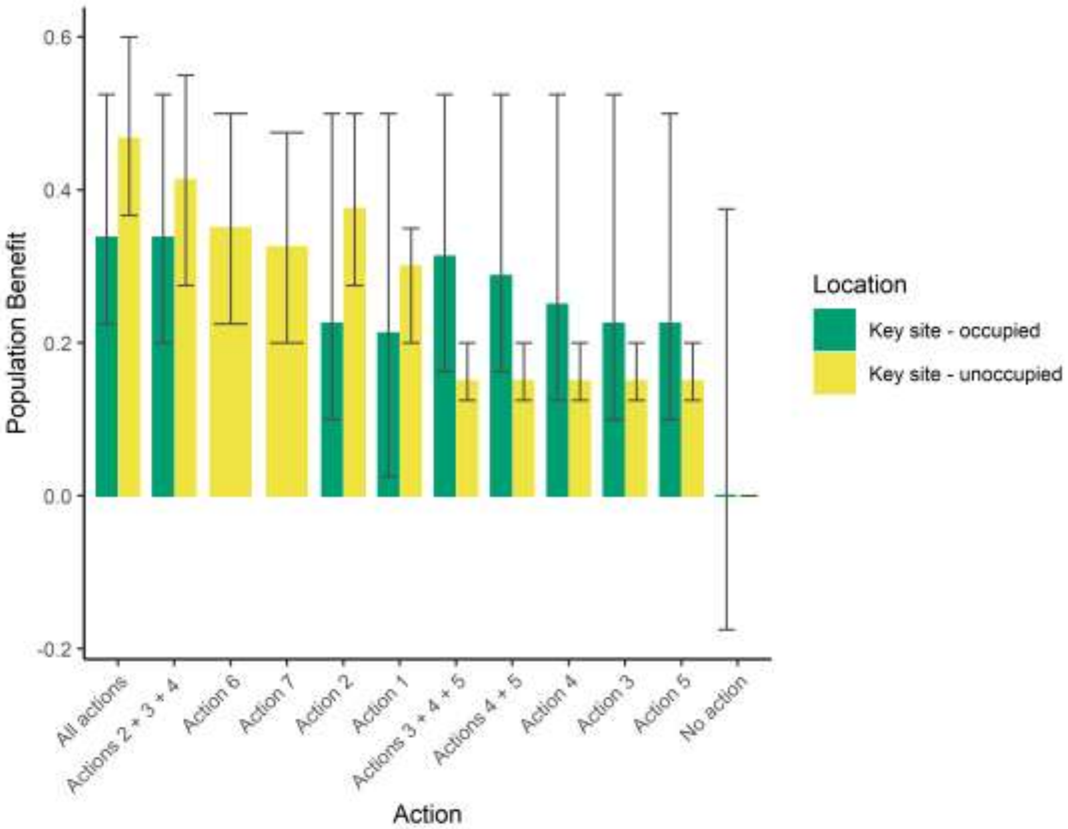

Figure 17. Mean change in Sloane's Froglet probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Experts determined that there are many potential actions available for Sloane's Froglet which would result in an improved probability of persistence. Across all locations, habitat restoration and manipulation to improve the quality of key sites (action 2) was deemed the most beneficial single action. When assessing the mean across locations, translocating into currently unoccupied habitat was found to have the greatest potential benefit of a single action. It was predicted that re-introduction into known former habitat (action 6) would have a slightly higher benefit than re-introduction via experimental release within or outside the species range (action 7).

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Species: Baw Baw Frog (BBF; *Philoria frosti*)

Number of experts: 5

Locations:

Alpine/Sub-alpine/Montane

Current population in Victoria: Endemic to Victoria, known only from the Mt Baw Baw plateau, considered to be one population. Actions could occur at one key site in suitable occupied habitat and suitable unoccupied habitat.

#	Actions:	
	No Action	No management of wild populations
1	Expand conservation breeding program (CBP)	Expand current CBP to include additional institutions, Melbourne Zoo manages two facilities with a small number of animals held at the Amphibian Research Centre. Develop additional long-term capacity at another location to better assist with conservation breeding for reintroduction.
2	Gene mixing	Analyse genetic structure of CBP population and conduct detailed pedigree analysis to determine ideal breeding plan to maximize genetic health.
3	Species specific chytrid research	Conduct research to investigate BBF chytrid susceptibility and immunity. Assuming immunity can be identified embed results into conservation breeding program and produce BBF for release at key site/s.
4	Develop assisted reproductive techniques (ART)	Using ART selectively breed BBF to enhance captive breeding, maximize genetic diversity and potentially selectively breed for chytrid resistance. Embed into CBP to produce stock for release at key site. Release and monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Habitat creation/restoration/manipulation	Use manual techniques to establish disease free breeding enclosures in sub-alpine and montane habitat to promote breeding and development of all life stages.
6	Protection of breeding sites	Fence key breeding sites in montane habitat to protect from feral herbivores and predators.
7	Population Augmentation and Genetic Rescue	Translocate captive bred animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
8	Populations Re-establishment	Translocate captive bred animals to extirpated BBF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on BBF at a site are low or can be reduced.
9	Population Establishment via Experimental Release	Translocate captive bred animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new BBF populations at new sites where the impacts of one or more threats on BBF are low or can be reduced.

Based on expert assessment the benefit of each action at each location for this species is as follows:

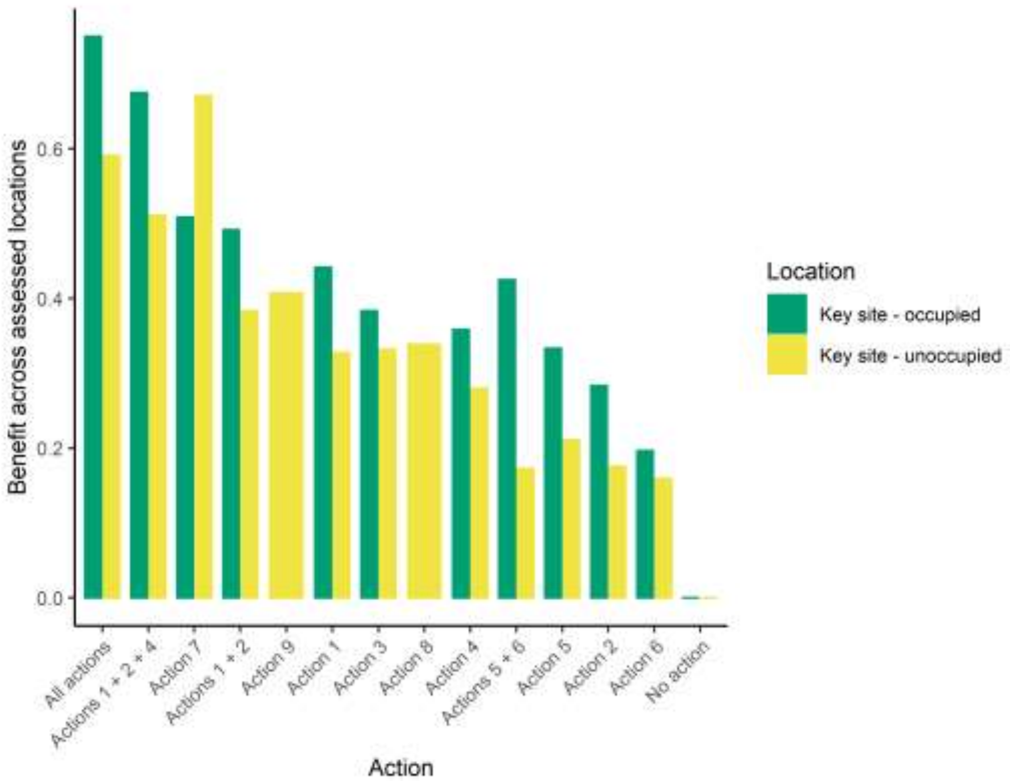

Figure 18. Benefit of each action/location combination to the Baw Baw Frog overall persistence probability across all assessed locations.

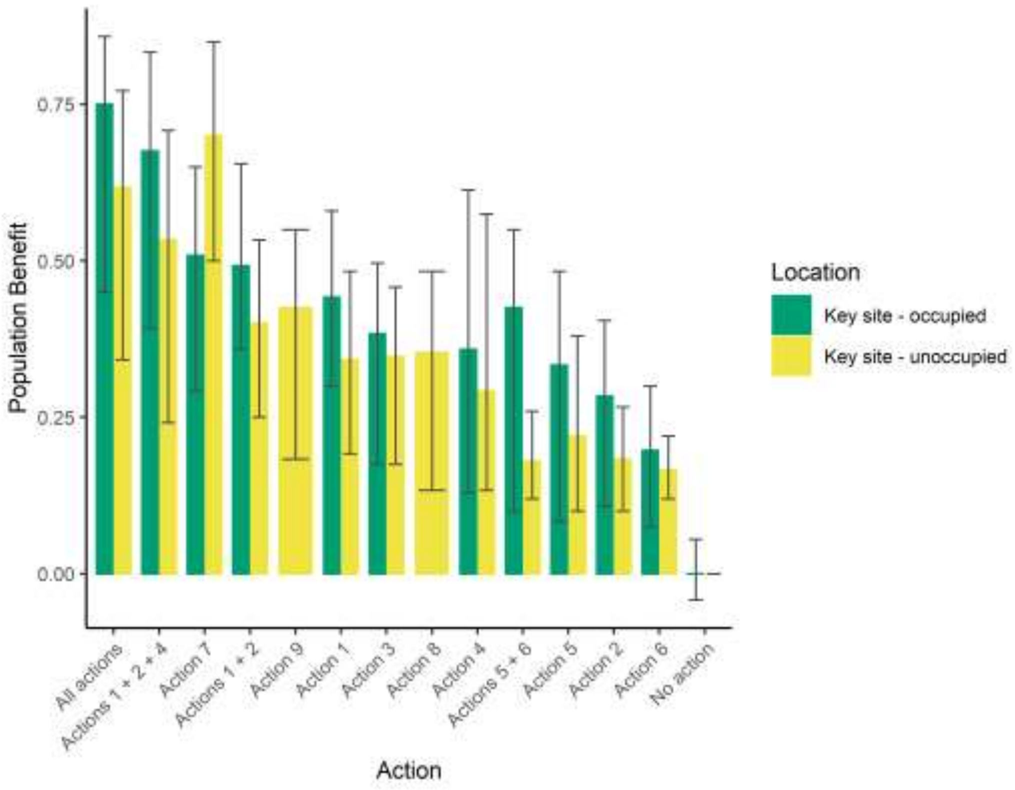

Figure 19. Mean change in Baw Baw Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Experts determined that the Baw Baw Frog has many potential actions which would result in an improved probability of persistence. These were consistent whether assessing benefit across or at each location. While a collection of actions (around strategic breeding and research for improved resilience) was found to be the most beneficial, the two highest ranked single action was Population Establishment via Experimental Release (action 7). This involves translocation and supplementation of areas which have lower or more manageable exposure to threats.

Species: Alpine Tree Frog (ATF; *Litoria verreauxii alpina*)

Number of experts: 5

Locations:

Alpine/Sub-alpine/Montane

Current population in Victoria: Remnant populations largely confined to Mt Hotham and the Dargo high plains. Actions could occur at one key site in suitable habitat and suitable unoccupied habitat.

#	Actions:	
	No Action	No management of wild populations.
1	Conservation breeding program (CBP)	Establish captive insurance population to breed ATF for release (annually n=500). Release at key site and monitor survival and breeding of ATF via mark-recapture and other survey methods as part of the species long-term monitoring program.
2	Gene mixing	Analyse genetic structure of extant populations and determine if gene mixing will improve wild genetic structure. Embed into CBP and utilise captive bred stock for release to key site/s, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
3	Species specific chytrid research	Conduct research to investigate ATF chytrid susceptibility and immunity. Assuming immunity can be identified embed results into conservation breeding program and produce ATF for release at key site/s. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
4	Population Augmentation and Genetic Rescue	Translocate captive bred animals or wild produced animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
5	Habitat restoration/manipulation	Use manual techniques to improve the quality and permanence of breeding habitat at key site/s. This may include construction and maintenance of natural or artificial breeding ponds that promote larval development through to metamorphosis.
6	Protection of breeding sites	Fence key breeding ponds to protect from feral herbivores, predators, and quarantined from CFA use.
7	Planned burning	Mapping key site/s (current DELWP project and BRATS report) to ensure planned burning does not negatively impact important habitat.
8	Populations Re-establishment	Translocate captive bred animals or wild produced animals to extirpated ATF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on ATF at a site are low or can be reduced.
9	Population Establishment via Experimental Release	Translocate captive bred animals or wild produced animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new ATF populations at new sites where the impacts of one or more threats on ATF are low or can be reduced.

Based on expert assessment the benefit of each action at each location for this species is as follows:

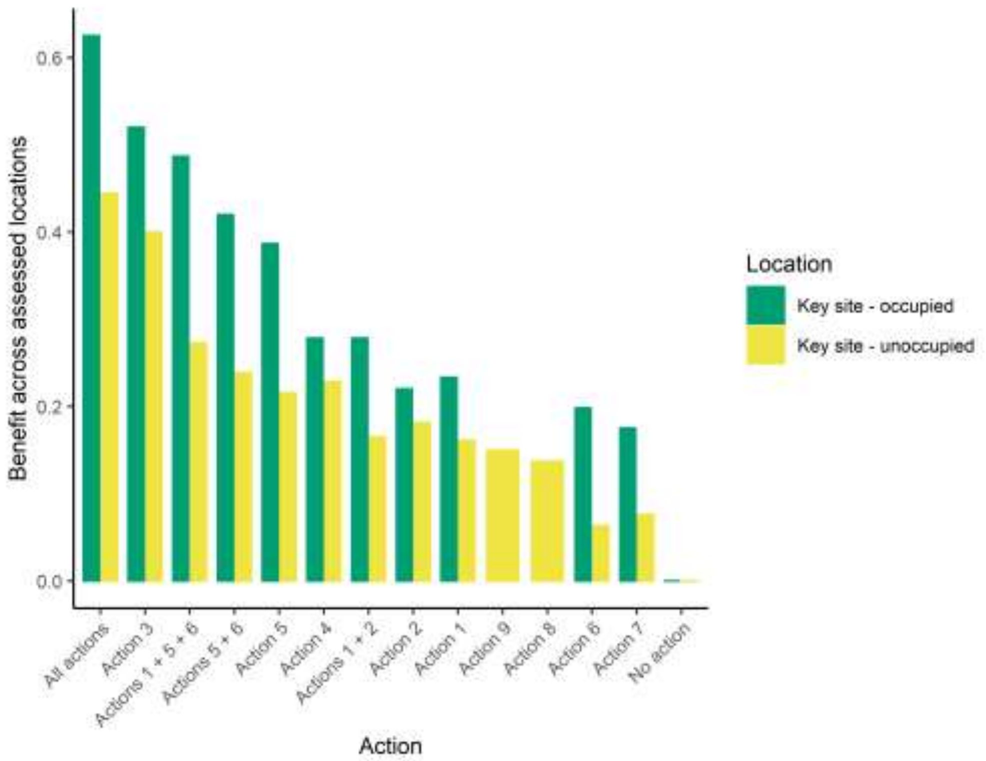

Figure 20. Benefit of each action/location combination to the Alpine Tree Frog overall persistence probability across all assessed locations.

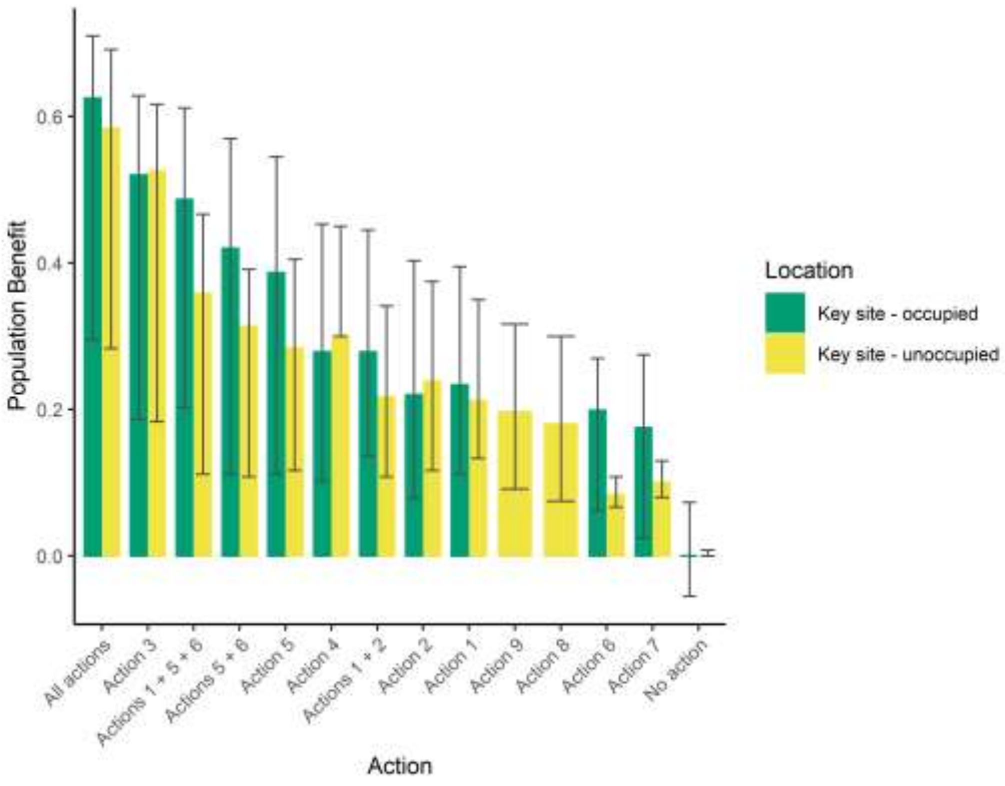

Figure 21. Mean change in Alpine Tree Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

The Alpine Tree frog demonstrates a relatively smooth decline in potential benefit of ranked, ranging from just over 0.6 to just under 0.2. These were consistent whether assessing benefit across or at each location. The highest ranked single action was conducting research to investigate chytrid susceptibility and immunity in this species (action 3). If an immunity trait could be identified, this could be disseminated and monitored through the population as part of a conservation breeding and tracking program. The actions considered next highest in terms of benefit, are a combination which prioritise protection and restoration key habitat, including breeding sites, through improved management and exclusion of existing threats.

Species: Spotted Tree Frog (STF; *Litoria spenceri*)

Number of experts: 5

Locations:

Actions could occur at one key site in suitable occupied habitat and suitable unoccupied habitat.

Current population in Victoria: All remaining populations are recognised as belonging to one of three distinctive genetic groups or Evolutionary Significant Units (ESU): the Upper-Murray, Wonnangatta and Goulburn ESU’s.

#	Actions:	
	No Action	No management of wild populations.
1	Conservation breeding (maintain ESU genetics) for release	Establish captive insurance population to breed STF for release (annually n=500) and maintain as separate ESU units. Release at key site and monitor survival and breeding of STF via mark-recapture and other survey methods as part of the species long-term monitoring program.
2	Conservation breeding (ESU gene mixing) for release	Establish captive insurance population to breed STF for release. Conduct genetic analysis of founder individuals and breed STF in captivity as one genetic population (gene mixing between ESUs as described by genetic analysis). Release at key site and monitor survival and breeding of STF via mark-recapture and other survey methods as part of the species long-term monitoring program.
3	Introduced predatory fish management	Working with Victorian angling community and other stakeholders reduce non-native predatory fish at a key site. Following removal of predatory fish use captive bred STF to supplement existing population, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques. Continue to monitor and manage introduced predatory fish population and conduct active removal when required.
4	Species specific chytrid research	Conduct chytrid research to investigate STF immunity. Assuming immunity is identified embed results into conservation breeding program and produce chytrid resistant STF for release at key site. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Develop assisted reproductive techniques (ART)	Using ART selectively breed STF to enhance captive breeding, maximize genetic diversity and potentially selectively breed for chytrid resistance. Embed into conservation breeding program to produce stock for release at key site. Release and monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
6	Population Augmentation and Genetic Rescue	Translocate captive bred animals or wild produced animals to extant wild populations. This approach is useful for small populations that have a low genetic diversity.
7	Populations Re-establishment	Translocate captive bred animals or wild produced animals to extirpated STF sites. This approach is useful to re-establish locally extinct populations when the impacts of one or more threats on STF at a site are low or can be reduced.
8	Population Establishment via Experimental Release	Translocate captive bred animals or wild produced animals to new sites within or outside of the species current distribution. This approach is useful to try to establish new STF populations at new sites where the impacts of one or more threats on STF are low or can be reduced.
9	Habitat restoration/manipulation	Use manual techniques to improve the quality at key site. Following habitat restoration use captive bred STF to populate/supplement habitat, monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
10	Planned burning	Mapping key site/s (current DELWP project and BRATS report) to ensure planned burning does not negatively impact important habitat.

Based on expert assessment the benefit of each action at each location for this species is as follows:

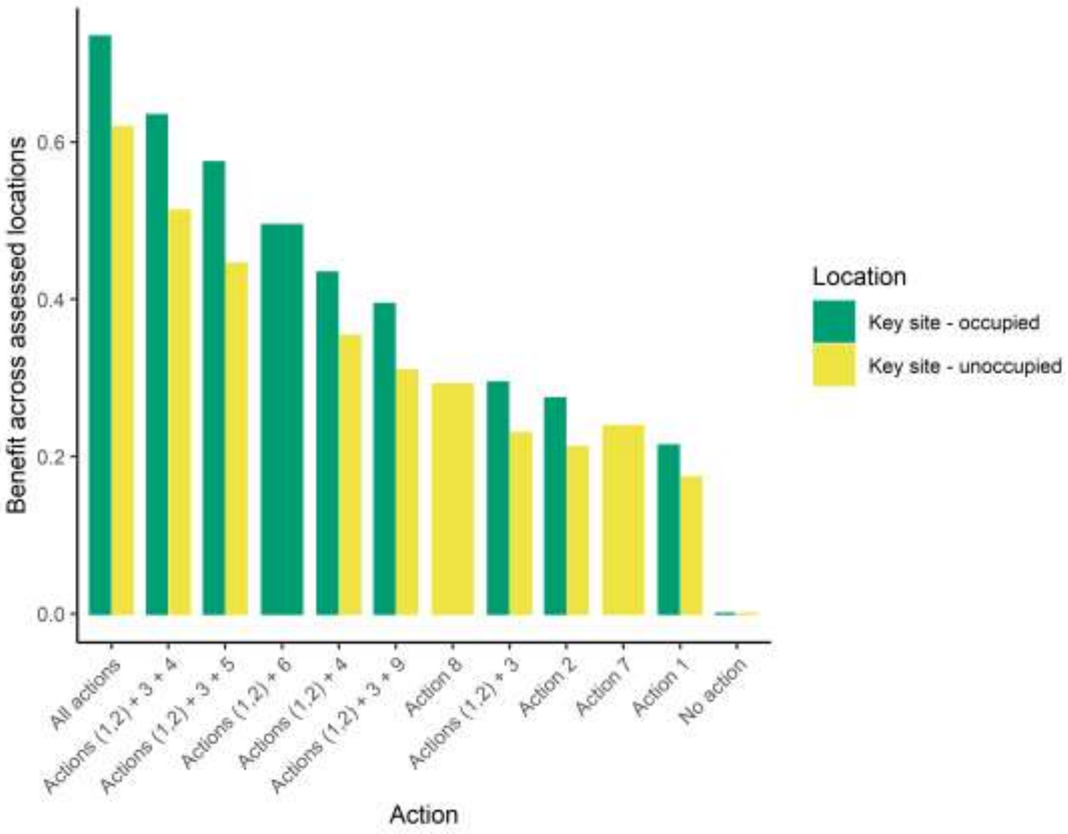

Figure 22. Benefit of each action/location combination to the Spotted Tree Frog overall persistence probability across all assessed locations

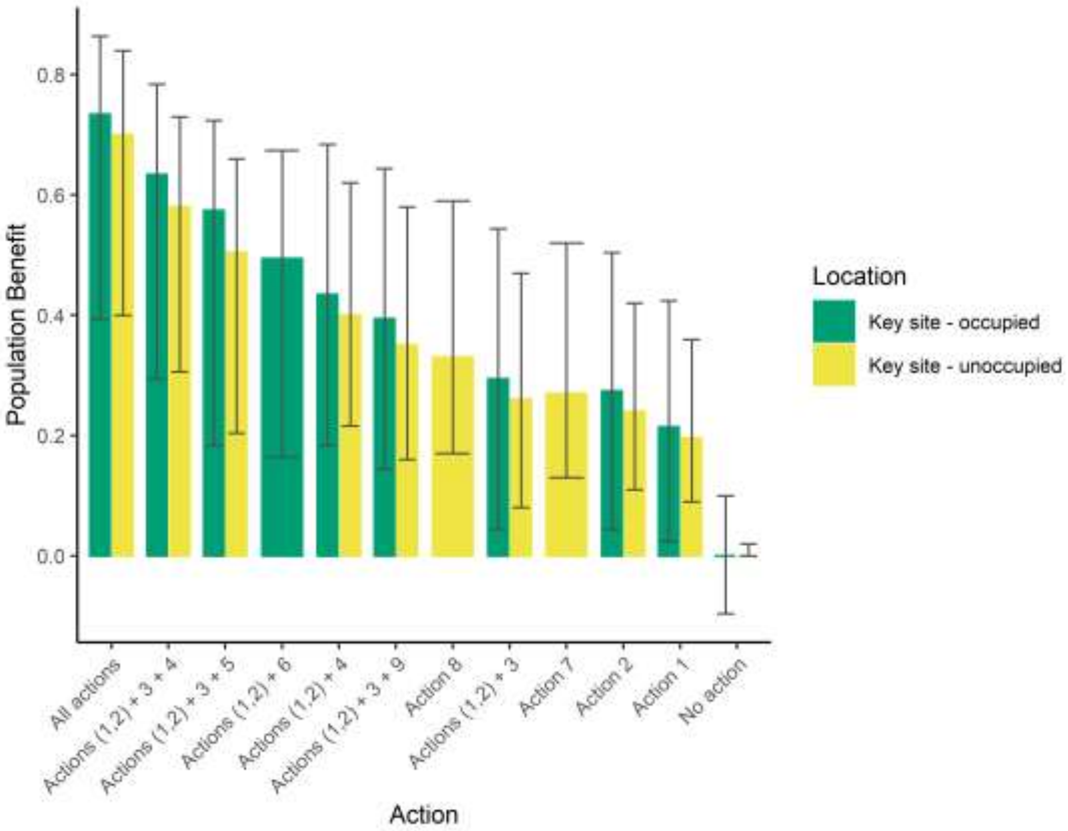

Figure 23. Mean change in Spotted Tree Frog probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Interpretation of Spotted Tree Frog results suggest a combination of actions is required for adequate improvement in probability of persistence. Actions 1 and 2 are very similar and so were conflated by experts in a combined assessment (therefore represented in brackets here). It was assumed they would not be able to occur independently at the same time, and a captive insurance population would be produced with an unknown mixture of ESUs, unless one condition (mixing or maintenance) was explicitly stated, and genetic analysis performed (represented as individual actions). Release at key site and monitoring of survival and breeding would be best supported by simultaneous management of threats: introduced predatory fish (action 3) and chytrid fungus (action 4).

Aquatic species

Introduction

Six species (including one genera complex representing 12 species of Galaxias) were selected based on workshop advice and alignment with Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and Victorian Flora and Fauna Guarantee Act 1988 (FFG Act) vulnerability. See supplementary report for reference material and further information.

Key knowledge gaps

I. Effect of grazing control on riparian habitat dependant animals

This model examines how grazing pressure from stock effects riparian habitat, and how control through fencing could impact riparian dependant animals. The quality of riparian habitat has flow on effects for the health of aquatic animals, through healthy vegetation, animals, and water quality. Aquatic species of interest in this model are generalisable beyond the six species chosen for Specific Needs assessment.

Below are the best- and worst-case scenarios for this condition followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

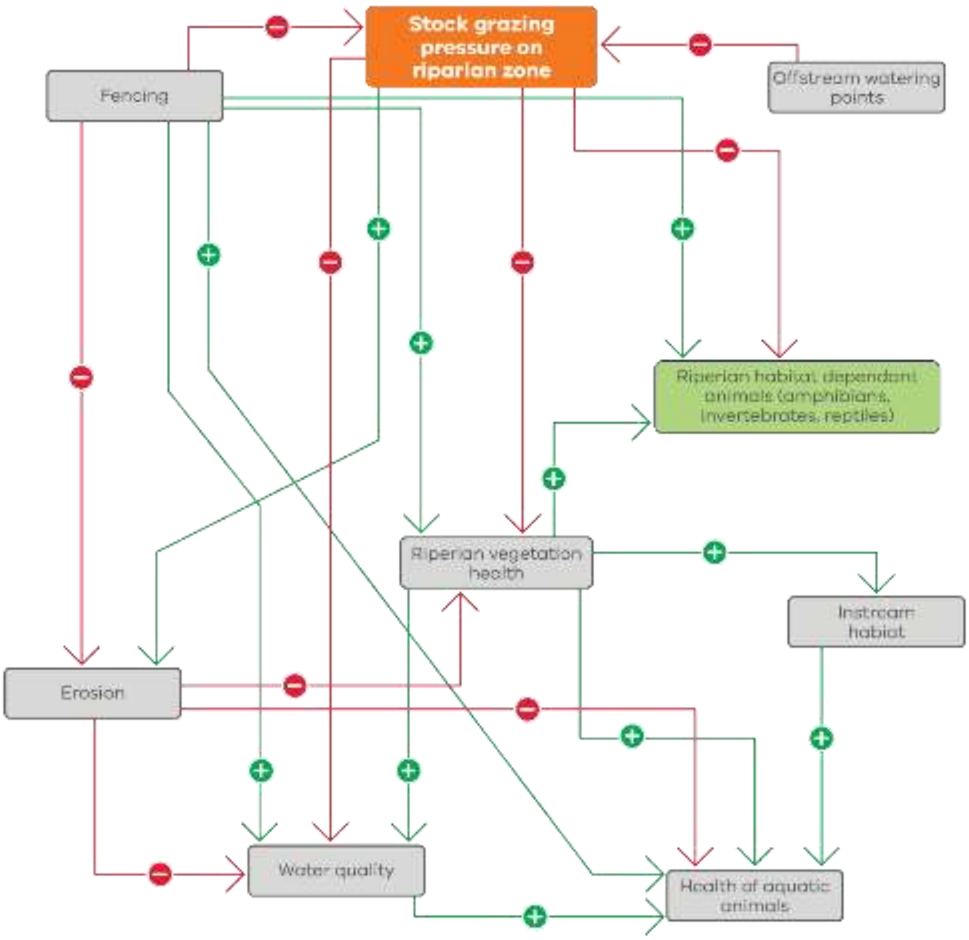

Figure 24. Best case scenario casual model for effect of grazing control on riparian habitat dependant animals. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

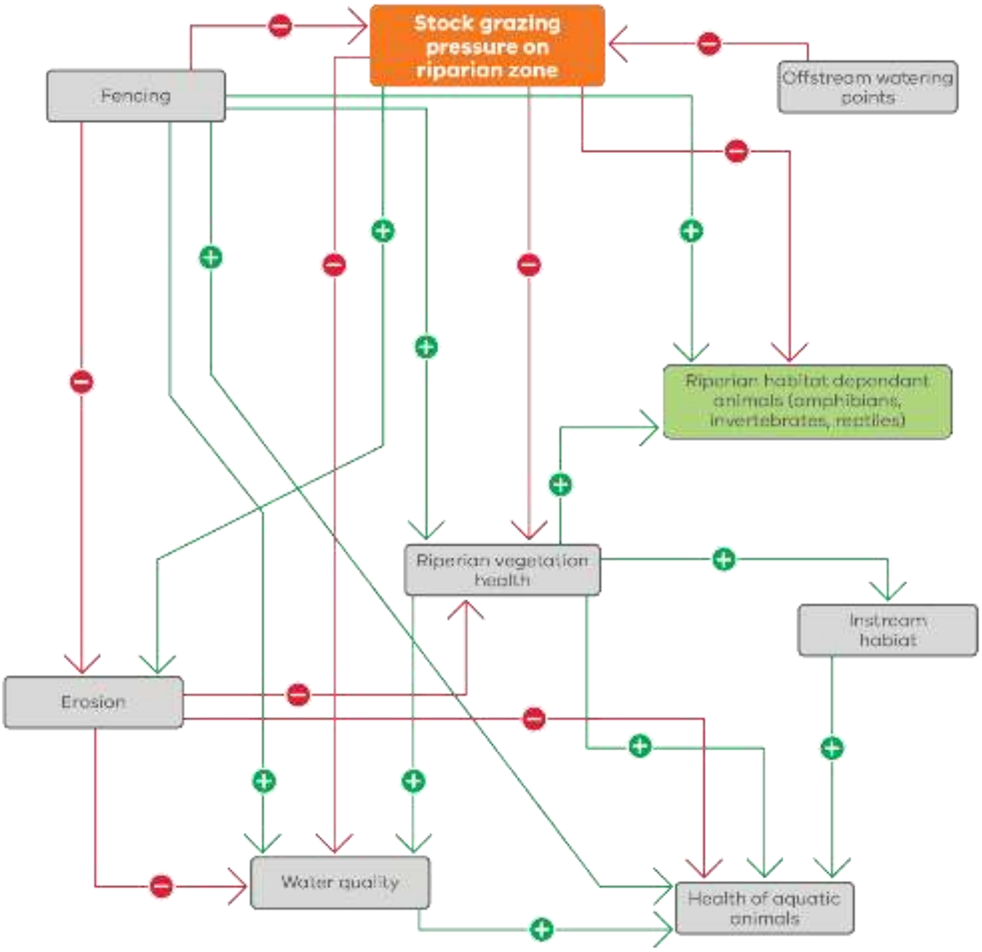

Figure 25. Worst case scenario casual model for effect of grazing control on riparian habitat dependant animals. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Fencing	Water quality	0.500
2	Offstream watering points	Stock grazing pressure on riparian zone	0.392
3	Stock grazing pressure on riparian zone	Water quality	0.108

Figure 26. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for grazing control on riparian habitat dependant animals

The table (Figure 26) for this problem-response scenario depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted). The highest ranked links of the effect of fencing on water quality, followed by effect of off stream watering points on stock grazing pressure on riparian zones might be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.5 and 0.4 respectively.

II. Effect of trout control on native fish

This model examines how the density of trout and mitigating environmental factors impact native fish. It generalises beyond fish to consider conservation-dependant native fish, macroinvertebrates, and amphibians. This model is therefore generalisable beyond the six fish species chosen for Specific Needs assessment.

Below are the best- and worst-case scenarios for this followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

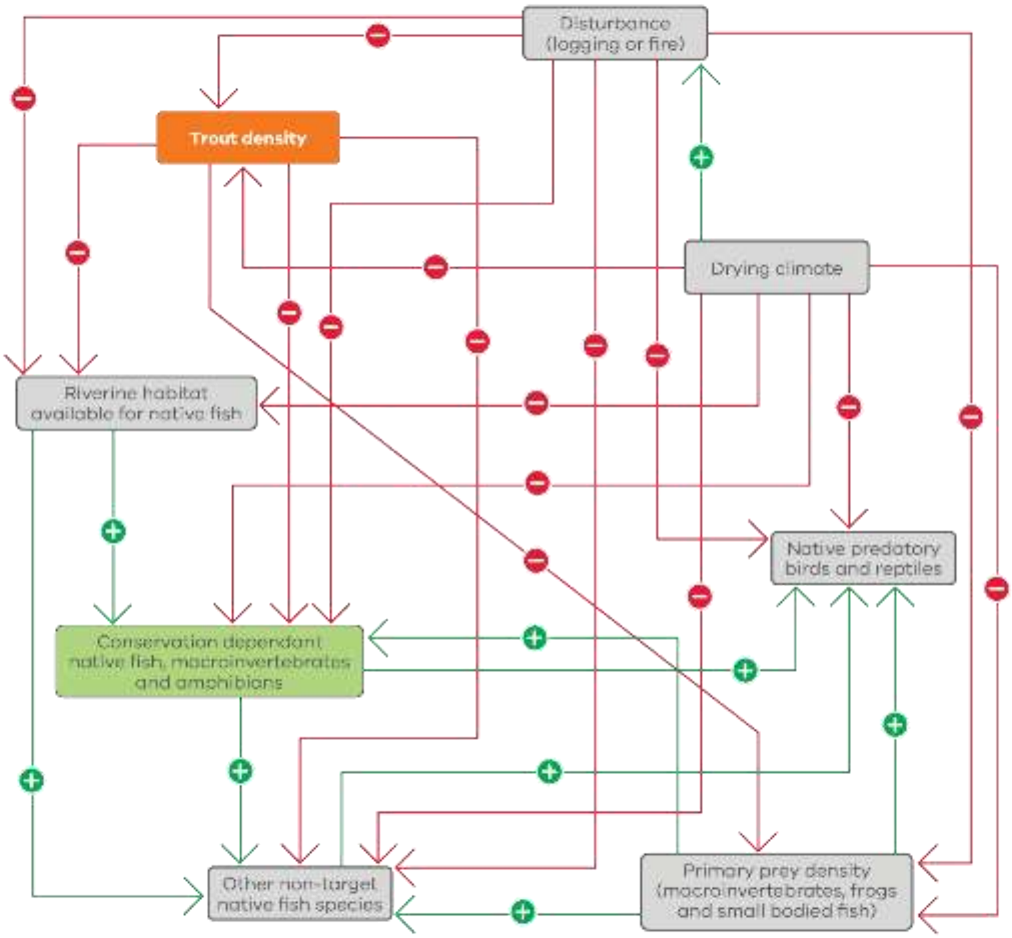

Figure 27. Best case scenario casual model for effect of trout control on native fish. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

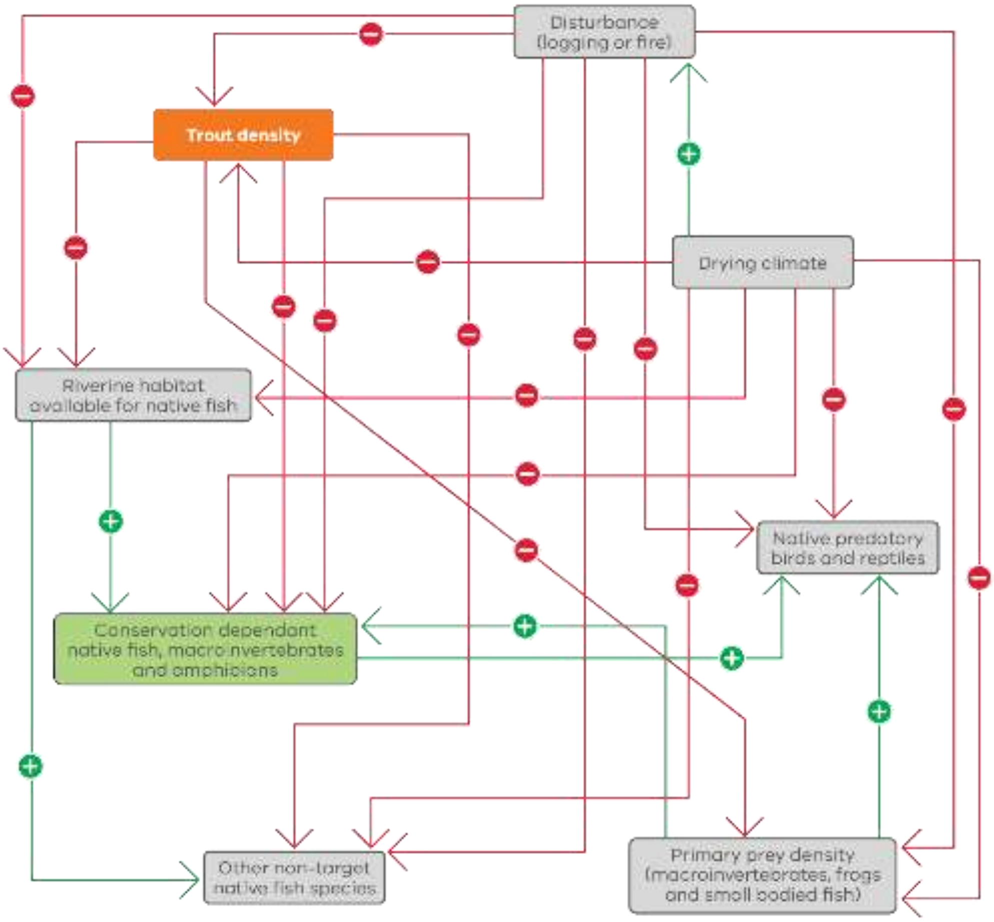

Figure 28. Worst case scenario casual model for effect of trout control on native fish. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Primary prey density	Other non target native fish species	0.188
2	Drying climate	Conservation dependant native animals	0.165
3	Drying climate	Trout density	0.153
4	Conservation dependant native animals	Other non target native fish species	0.125
5	Conservation dependant native animals	Native predatory birds and reptiles	0.114
6	Other non target native fish species	Native predatory birds and reptiles	0.108
7	Disturbance logging or fire	Riverine habitat available for native fish	0.085
8	Trout density	Primary prey density	0.034
9	Drying climate	Riverine habitat available for native fish	0.028

Figure 29. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements from trout control on native fish

The table (Figure 29) for this problem-response scenario depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren’t depicted). The highest ranked links of primary prey density on other non-target native fish species, as well as the effects on climate change on conservation dependant native species and trout density, might be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.19, 0.17 and 0.15 respectively. Other links display comparable reductions in uncertainty and may be highlighted as priorities through further investigation of expected gain.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 32 and 33) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Mountain Galaxiid species complex (*Galaxias olidus* 12 spp.)

In Gippsland this species complex is made up of at least twelve species, the majority of which are endangered and patchy in distribution. The species have a broad distribution on both sides of the Great Dividing Range (GDR) on mainland Australia, extending from near Toowoomba in southern Queensland, through New South Wales and Victoria, to Kangaroo Island in South Australia. The Gippsland region in Victoria is, however, a hotspot for many of the most endangered species in the complex. A group of small species (<135 mm in length), they occupy freshwater streams and larger rivers, commonly in foothill and montane areas and extending into alpine reaches, though are also found in lowland zones. All species of the complex complete their entire life cycle in freshwater and many populations are severely impacted by negative interactions with the predatory alien species Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*), leading to localised extirpations and fragmentation and geographic isolation of remaining populations. Populations can also be affected by inappropriate land use which leads to instream sedimentation, loss of habitat and increased water salinity, and from alteration to flow regimes.

Number of experts: 2

Locations:

Gippsland (from west to east)

Current population in Victoria: The Gippsland region has the highest concentration of endangered galaxiids in Victoria, Australia, and indeed the world, and therefore this region was chosen for elicitation.

#	Actions:	
	No action	As described.
1	Exotic fish control	Removal of redfin, carp, and trout where appropriate.
2	Install barriers	Install instream barriers to stop upstream incursion of trout.
3	Re-establish populations	Stock and translocate fish into river reaches within historical range to re-establish populations.
4	Undertake gene mixing	Enhancing genetic diversity (genetic rescue) by translocating and stocking fish among populations.
5	Identify drought refuges	Identify reaches of streams that act as refuges for taxa during drought.
6	Restore habitat	Restore instream and riparian habitat.

Based on expert assessment the benefit of each action at each location for this species is as follows:

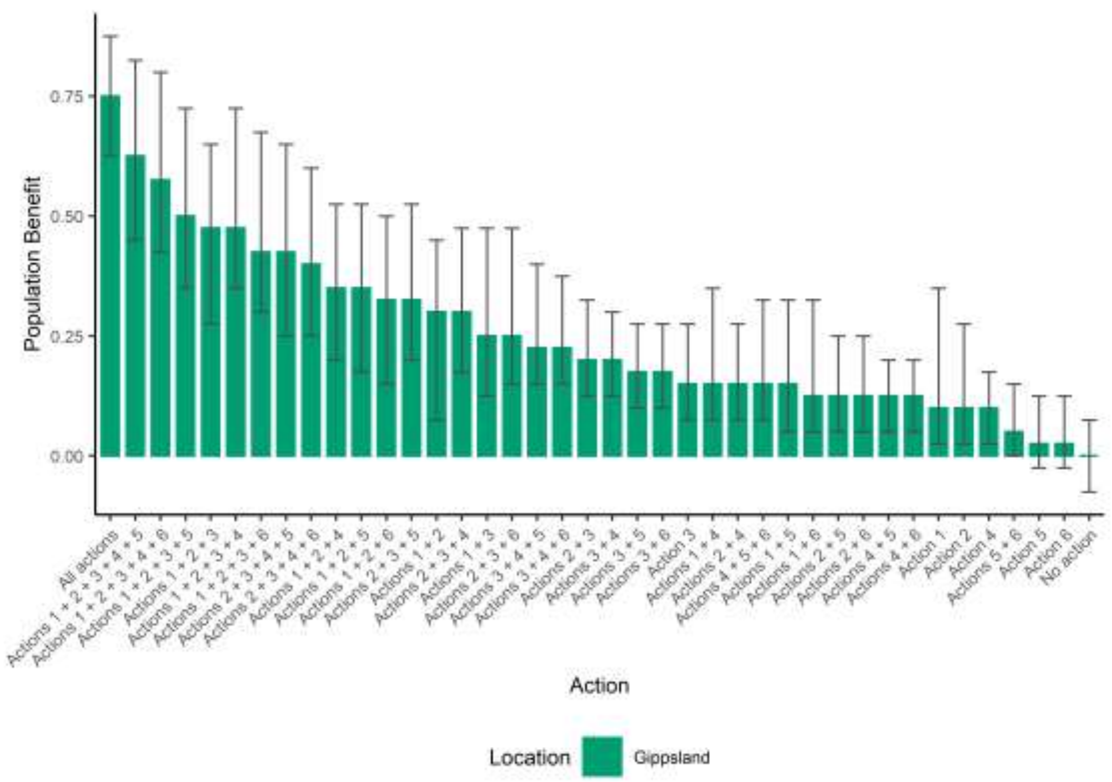

Figure 30. Mean change in *Galaxias olidus* species complex (12 spp.) probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

These results demonstrate a clear cumulative benefit to the species complex from multiple actions across Gippsland. The highest-ranking single actions relate to the control and exclusion of exotic fish (redfin, carp and trout) as well as the installation of barriers to stop upstream incursion. This suggests that while gene mixing and habitat protection is beneficial, the greatest gains can be obtained by controlling the threat posed by invasive fish.

Species: Yarra Pygmy Perch (*Nannoperca obscura*)

A small freshwater fish (< 75 mm) that is endemic to south-eastern Australia, from the Bunyip River basin in West Gippsland, to as far west as Lake Alexandrina and the Finniss River, near the mouth of the Murray River. Still widely distributed, but populations are fragmented and patchy across the landscape. It is likely that the species has suffered a significant and ongoing decline in abundance due to habitat changes to rivers, creeks, and shallow freshwater wetlands. Major threats to the Yarra Pygmy Perch include wetland drainage, climate change, habitat damage through grazing and lack of regeneration, and introduced fish competitors and predators.

Number of experts: 1

Locations:

All remaining populations of the Eastern Genetic lineage (Corangamite, Barwon, Moorabool & Maribyrnong).

Current population in Victoria: Although this species is widely distributed, it is patchy in distribution, and most remnant populations within the Corangamite, Barwon, Moorabool, and Maribyrnong catchments are likely to be known. For this reason, it was this eastern genetic linage that was chosen for elicitation.

#	Actions:	
	No action	As described.
1	Re-establish populations	Stock and translocate fish into river reaches within historical range to re-establish populations.
2	Undertake gene mixing	Enhancing genetic diversity (genetic rescue) by translocating and stocking fish among populations.
3	Identify drought refuges	Identify reaches of streams that act at refuges for taxa during drought.
4	Restore habitat	Restore instream and riparian habitat.

Based on expert assessment the benefit of each action at each location for this species is as follows:

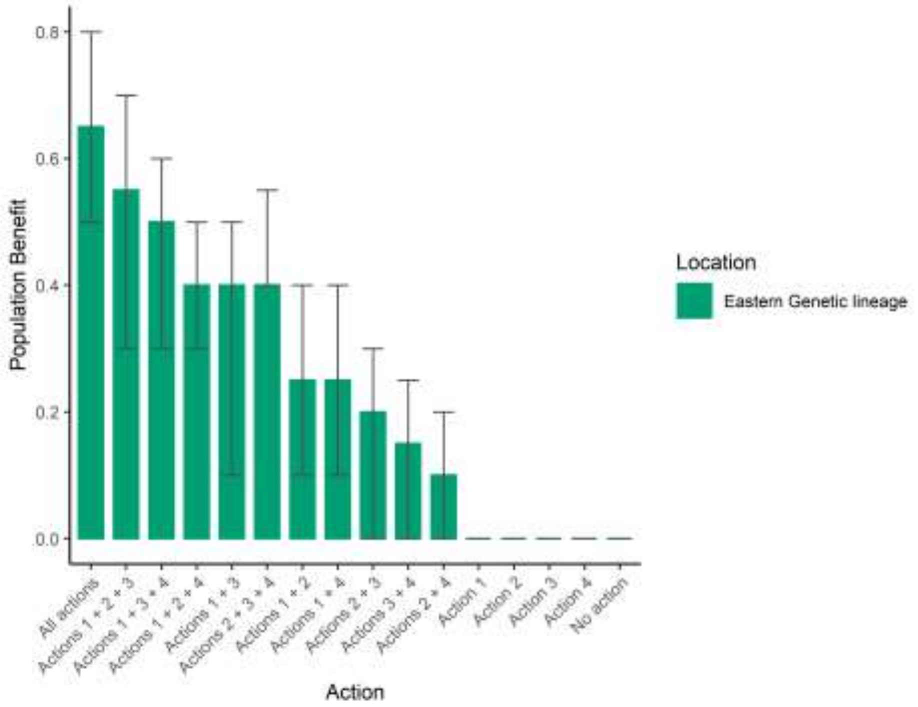

Figure 31. Mean change in Yarra Pygmy Perch probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

These results suggest that the Yarra Pygmy Perch requires a combination of actions to achieve a measurable benefit in the eastern genetic lineage. Three actions show a greater benefit to the population than two, and all actions achieve the highest value overall. Given the actions chosen in this assessment, this species is likely exposed to general broad-scale threats and requires a boost in resilience across its entire range to ensure future persistence.

Species: Macquarie Perch (*Macquaria australasica*)

A moderate sized freshwater fish that was once widespread throughout the Murray-Darling Basin (particularly upstream reaches) and parts of south-eastern coastal NSW. The species has however, undergone widespread declines in abundance and distribution, and is now absent from much of its former range. In Victoria, self-sustaining populations are present in the upper tributaries of the Goulburn-Broken river system, the Ovens River catchment and the upper Mitta Mitta River and the Yarra River. Threats proposed for the species are habitat degradation, introduction of exotic fish species, barriers to fish movement, altered flow and thermal regimes, disease and parasites, illegal/incidental capture, water pollution and climate change.

Number of experts: 2

Locations:

Lake Dartmouth and tributaries, Goulburn-Broken populations, Buffalo and Ovens rivers and Yarra River.

Current population in Victoria: As this species occurs in Victoria in the upper tributaries of the Goulburn-Broken river system, the Ovens River catchment the upper Mitta Mitta River, and the Yarra River, all of which are important for the species conservation, these location were chosen for elicitation.

#	Actions:	
	No action	As described.
1	Education and fisheries regulations	Signage, community engagement and fisheries patrols / regulations.
2	Restore habitat	Restore instream and riparian habitat.
3	Protect natural flows	Protect natural flow regimes required for the completion of critical life stages (limit extraction where necessary).
4	Exotic fish control	Removal of redfin, carp, and trout where appropriate.
5	Undertake gene mixing	Enhancing genetic diversity (genetic rescue) by translocating and stocking fish among populations.
6	Provide e-flows	Provide appropriate flows in regulated system (environmental flows) required for the completion of critical life stages.
7	Protect water quality	Control pollution and water quality in urban environments.
8	Provide appropriate flow	E-flows or protecting low flows.
9	Re-establish populations	Stock and translocate fish into river reaches within historical range to re-establish populations.

Based on expert assessment the benefit of each action at each location for this species is as follows:

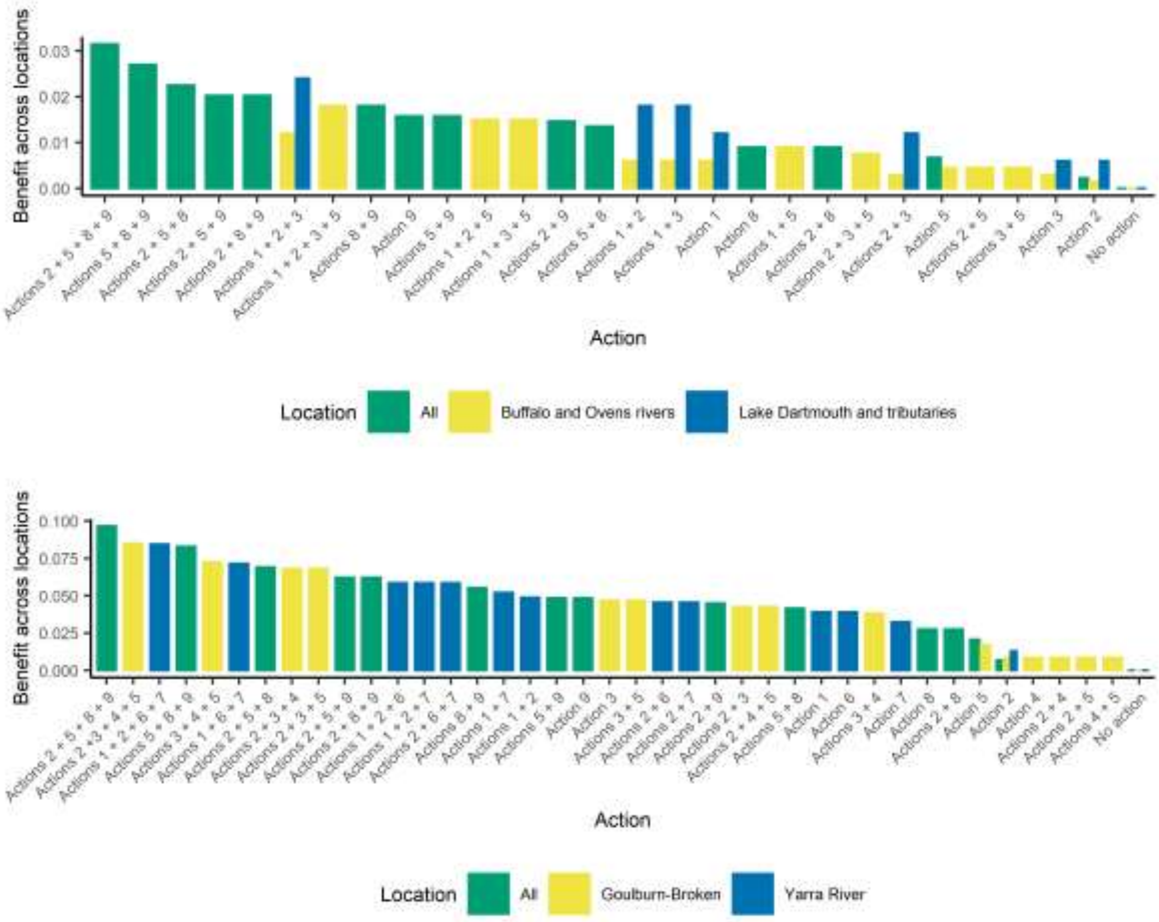

Figure 32. Benefit of each action/location combination to the Macquarie Perch overall persistence probability across all assessed locations.

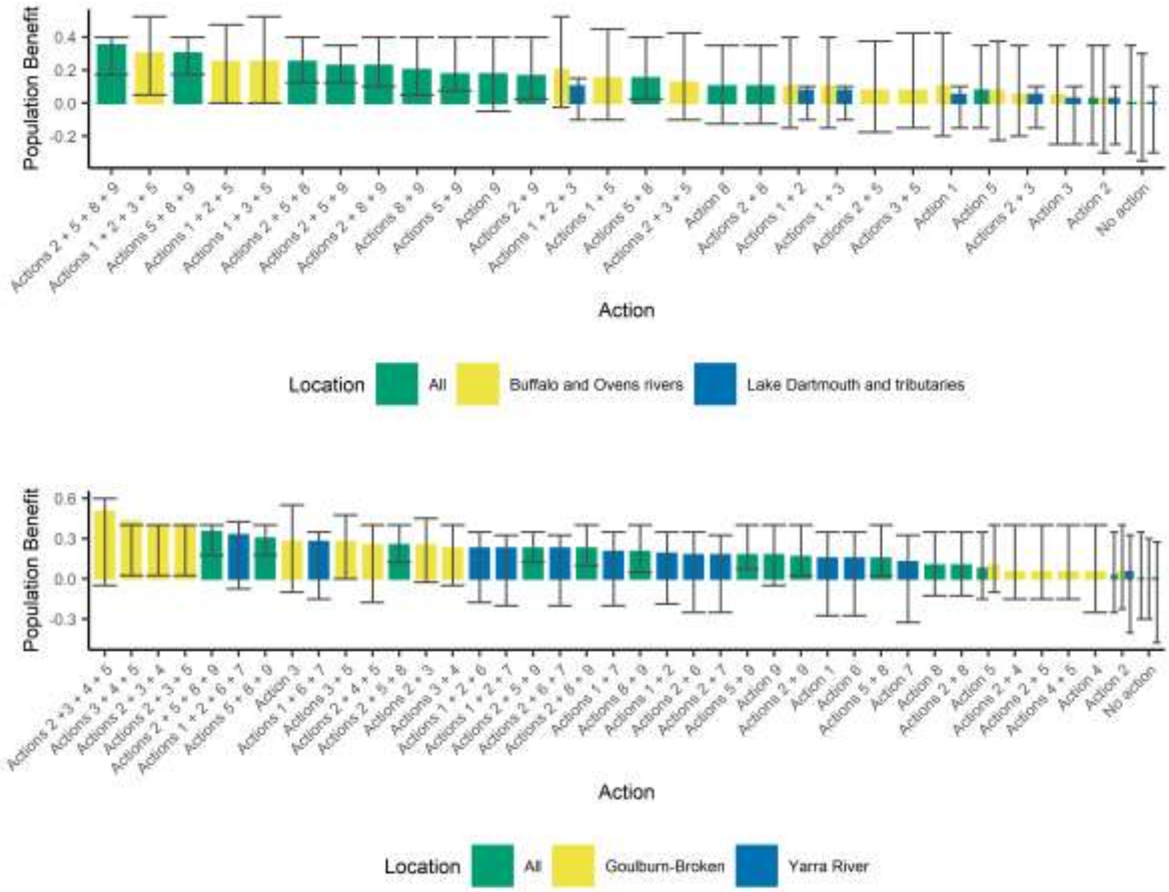

Figure 33. Mean change in Macquarie perch probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Interpretation of Macquarie Perch results suggest a combination of actions is required for adequate improvement in probability of persistence. However, when considering which combination or which actions are most beneficial, will be location-dependant. Across all locations, action 9 (re-establish populations) shows the greatest single benefit, with the creation of a new population within the historical range having a greater benefit in persistence at that location than if the species remained locally extinct.

Species: Glenelg Freshwater Mussel (*Hyridella glenelgensis)*

Occurs in the Glenelg–Wannon river system in south-western Victoria. The species has rarely been reported since its discovery in 1898, and there are no records from the late 1920s until 1990, and again in 2000, when small numbers were found in the Crawford River, a tributary of the Glenelg River. The mussels prefer sandy sediment in flowing reaches where there is instream woody debris and overhanging vegetation. In these areas, the main threats are land clearance and stock access to the channel and riparian areas.

Number of experts: 3

Locations:

Crawford R; Glenaulin Crk, Moleside Crk

Current population in Victoria: This species only occurs in the Glenelg–Wannon river system in south-western Victoria, therefore this location was chosen for the species.

#	Actions:	
	No action	As described.
1	Protect groundwater	Maintain GW levels to maintain discharge during dry periods and drought.
2	Protect natural flows	Protect natural flow regimes required for the completion of critical life stages (limit extraction where necessary).
3	Restore habitat	Restore instream and riparian habitat.
4	Artificial breeding	Undertake captive breeding.
5	Undertake gene mixing	Enhancing genetic diversity (genetic rescue) by translocating and stocking fish among populations.

Based on expert assessment the benefit of each action at each location for this species is as follows:

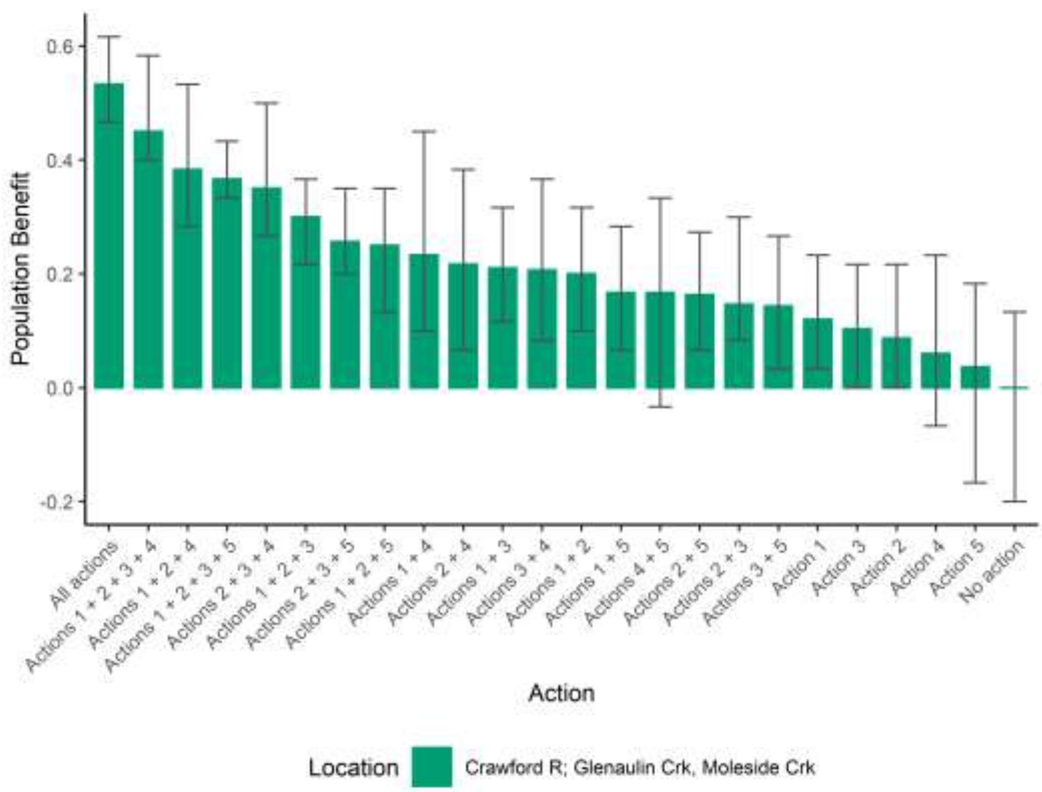

Figure 34. Mean change in Glenelg Freshwater Mussel probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

For the Glenelg Freshwater Mussel, as with other species, the greatest benefit is obtained through a combination of actions across its known range. Protecting ground water (action 1) shows the greatest single benefit, which suggests the species experiences a high threat of desiccation during periods of drought or dryness. There appears to be reasonable disagreement amongst experts on the merits of artificial breeding (action 4) and gene mixing (action 5) for this species.

Species: Estuary Perch (*Percalates colonorum)*

A catadromous, long-lived (> 40 years) fish that inhabits tidal reaches of rivers, lakes and coastal lagoons from the Richmond River in northern New South Wales (NSW) to the mouth of the Murray River in South Australia. Historically, the species was also present in several rivers and streams in the north of Tasmania, but only one remnant population is now known to persist in that state. Although still abundant at some locations, in recent years the species has also undergone a decline in many of the rivers within its range, likely as a response to fishing pressure, flow regulation, habitat degradation, and climate change.

Number of experts: 2

Locations:

Regulated river systems (Snowy, Thomson, Latrobe, Bunyip-Tarago, Yarra, Werribee, Moorabool, Barwon, Glenelg rivers), Non-regulated coastal rivers and Coastal rivers in Victoria

Current population in Victoria: Due to this species residing mostly in estuaries in Victoria, and the time constraints of the project, locations in Victoria were split into unregulated, versus nonregulated coastal river systems, while the implementation of a closed season was assessed on a state-wide basis.

#	Actions:	
	No action	As described.
1	Provide e-flows	Provide appropriate flows in regulated system (environmental flows) required for the completion of critical life stages.
2	Protect natural flows	Protect natural flow regimes required for the completion of critical life stages (limit extraction where necessary).
3	Restore habitat	Restore instream and riparian habitat.
4	Install fishways/remove barriers	Install or upgrade fishways, or remove barriers to provide unimpeded passage.
5	Closed season	Establish a no take period for the species over the time it is known to congregate and spawn (i.e. mid to late spring).

Based on expert assessment the benefit of each action at each location for this species is as follows:

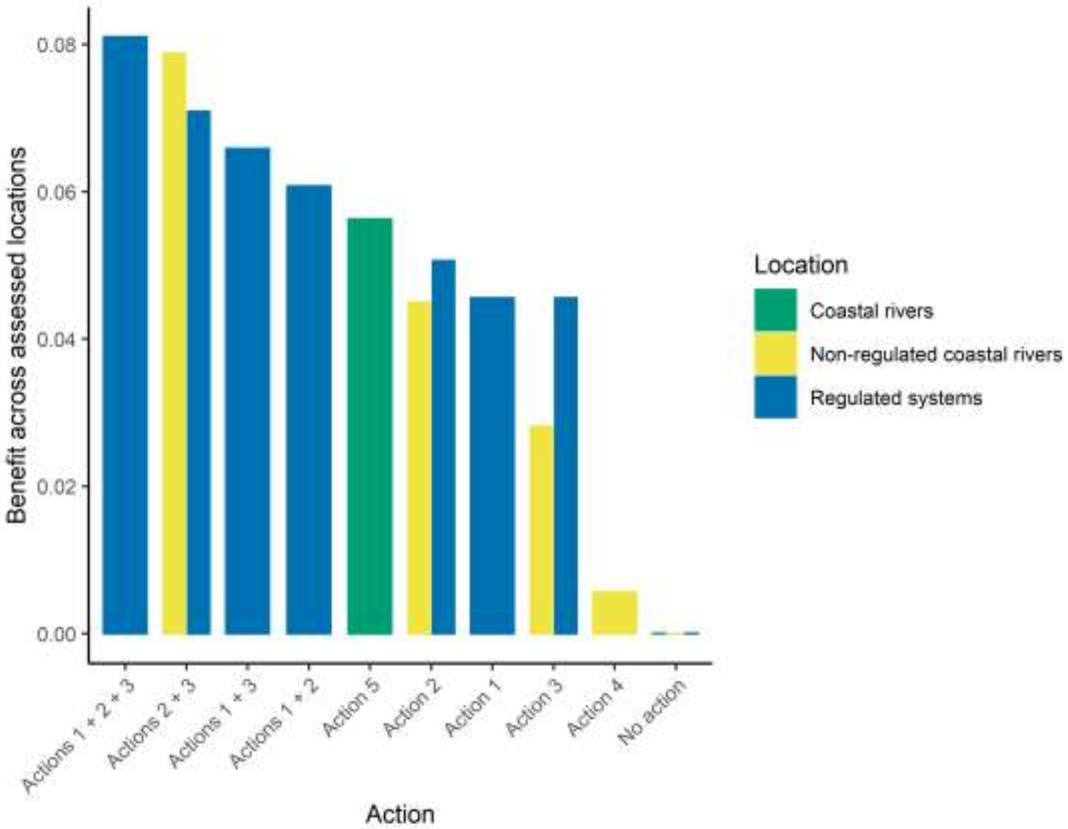

Figure 35. Benefit of each action/location combination to the Estuary Perch overall persistence probability across all assessed locations.

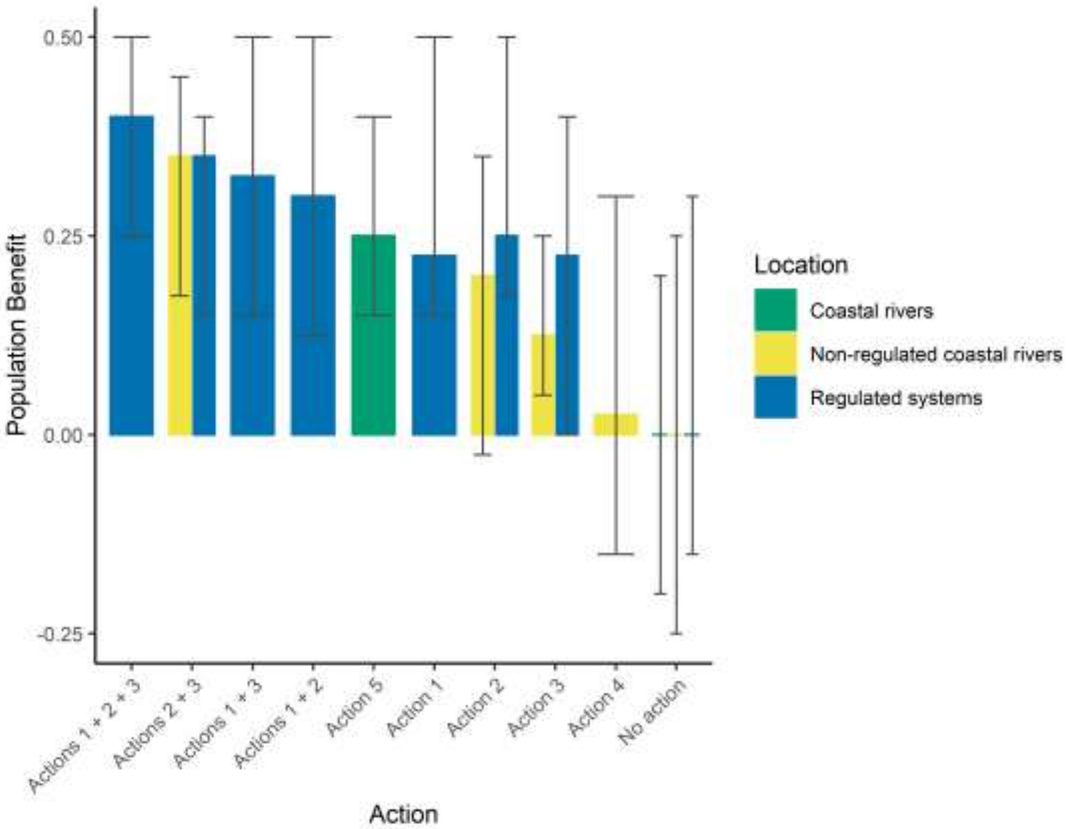

Figure 36. Mean change in Estuary Perch probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Actions for this species are strongly dependant on the location considered. A closed season (action 5) is seemingly the only appropriate option in coastal rivers, while the protection of flows (environmental and natural) is critical for the long term persistence of Estuary Perch in non-regulated coastal rivers and regulated systems.

Species: Australian Grayling (*Prototroctes maraena*)

A short-lived fish species (2–3 years), endemic to south-eastern Australia, including coastal rivers of Victoria, Tasmania, and New South Wales. It was once abundant throughout its range but is now patchily distributed. Precise causes of the decline of Australian Grayling are not known, but likely factors contributing to decline include barriers (such as dams and weirs) to migration in coastal rivers, changes to rivers including altered flow and temperature regimes and increased nutrient and sediment loads, and perhaps competition and predation from introduced fish species such as trout. The species is a diadromous species, migrating between rivers, estuaries, and coastal seas, and as a result relies on free access to a range of freshwater, estuarine and marine habitats for its survival.

Number of experts: 2

Locations:

Regulated systems (Snowy, Thomson, Latrobe, Bunyip-Tarago, Yarra, Werribee, Moorabool, Barwon, Glenelg rivers), Non-regulated coastal estuaries in Victoria and where required in coastal rivers of Victoria.

Current population in Victoria: Due to the extensive geographical distribution of this species, partnered with time constraints of the project, coastal rivers in Victoria were divided into unregulated (i.e. systems with large impoundments on them), versus nonregulated coastal river systems (systems with no large impoundments), while the instillation of fishways or removal of barriers - a critical aspect of this species conservation - was undertaken on a state-wide basis.

#	Actions:	
	No action	As described. No action estimates for sites other than current distribution, sites where no population present, have been assumed to be zero.
1	Provide e-flows	Provide appropriate flows in regulated system (environmental flows) required for the completion of critical life stages.
2	Protect natural flows	Protect natural flow regimes required for the completion of critical life stages (limit extraction where necessary).
3	Restore habitat	Restore instream and riparian habitat.
4	Install fishways/remove barriers	Install or upgrade fishways, or remove barriers to provide unimpeded passage.

Based on expert assessment the benefit of each action at each location for this species is as follows:

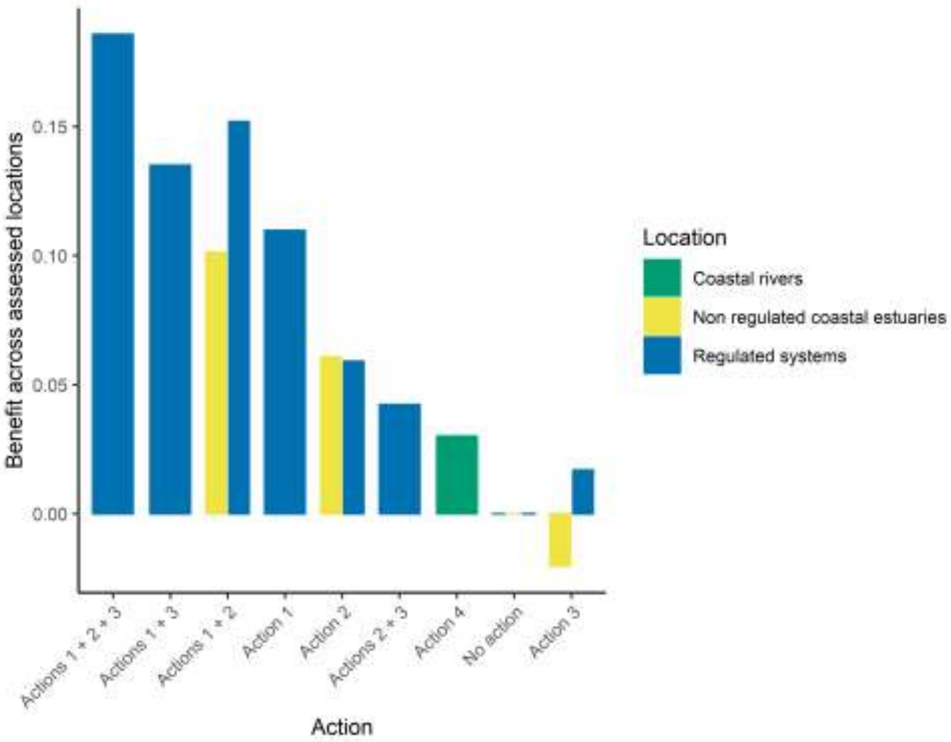

Figure 37. Benefit of each action/location combination to the Australian Grayling overall persistence probability across all assessed locations.

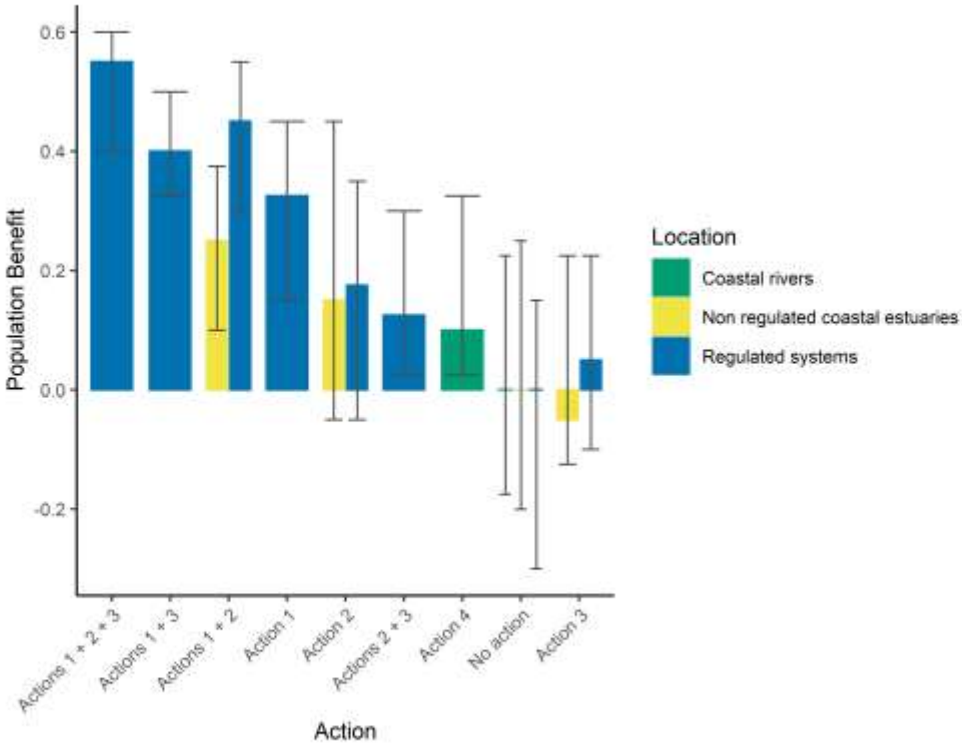

Figure 38. Mean change in Australian Grayling probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

As with previous species, the best actions for the Australian Grayling are strongly dependant on the location considered. Installing barriers (action 4) is the only appropriate option in coastal rivers, while the protection of flows (environmental and natural) is critical for the long-term persistence of Australian Grayling in non-regulated coastal rivers and regulated systems. Restoring habitat in non-regulated coastal estuaries shows a negative benefit as experts assessed the probability of persistence under a no action scenario as higher than under this management action scenario. No action estimates for sites other than current distribution (i.e. sites where no population is currently present) have been assumed to be zero.

Arboreal mammals, owls, and bats

Introduction

Taxon leads for this group chose to split the process, considering arboreal mammals and owls separately to bats. Discussions were held which resulted in seven species (two gliders, two owls and three bats) selected overall. The Southern Greater Glider was allocated as a priority species by DELWP. The glider/owl expert group then chose three other species primarily based on workshop ranking status and threat status. For the arboreal mammals, it was decided to exclude species that are currently the focus of significant conservation activities (e.g. Leadbeater's Possum and Mountain Pygmy Possum).

Bat species were selected primarily based on their vulnerability in Victoria. The Eastern Bent-Wing Bat was assessed at the subspecies level with the closely related subspecies, Southern Bent-Wing Bat (*Miniopterus orianae bassanii)*. However, the Eastern Bent-Wing Bat is referred to here as a 'species' for simplicity. The South-eastern Long-Eared Bat was selected because it is very rare and restricted in Victoria, occurring only in a small area in the north-west of the state where it roosts in tree hollows. In contrast, the two other species included are cave-dwelling bats that are widespread across eastern Victoria, but that only breed in one (or three for the EHSB) main maternity roost. These two cave-dwelling species share many of the same roosts and threats, but have different population sizes, and hence may show different responses to the proposed mitigating actions.

The experts were asked to consider several assumptions while undertaking their elicitation:

- Business-As-Usual (BAU) timber harvesting until 2030, then no harvesting (as per the Victorian Forestry Plan)
- No old growth harvesting (as per government commitments)
- Large trees (>2.5m DBH) are protected state-wide until 2030 (as per government commitments)
- Forest Protection Survey Program surveys continue until 2030
- Climate change predictions (as per Victorian Climate Projections)
- Impact of the Victorian Bushfires 2019-2020 and future bushfire regimes under climate projections
- Standard on-ground management actions occurred in a BAU manner (e.g. fire management etc)

See supplementary report for reference material and further information.

Key knowledge gaps

I. Effect of climate change on density of large possums, gliders, and owls

This model examines how climate change and its consequences impact the density of large possums, gliders, and owls. The model also incorporates potential management actions and explores how they may impact the system. Species of interest in this model are generalisable beyond the seven species chosen for Specific Needs assessment.

Below is a combined best- and worst-case scenario for this followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

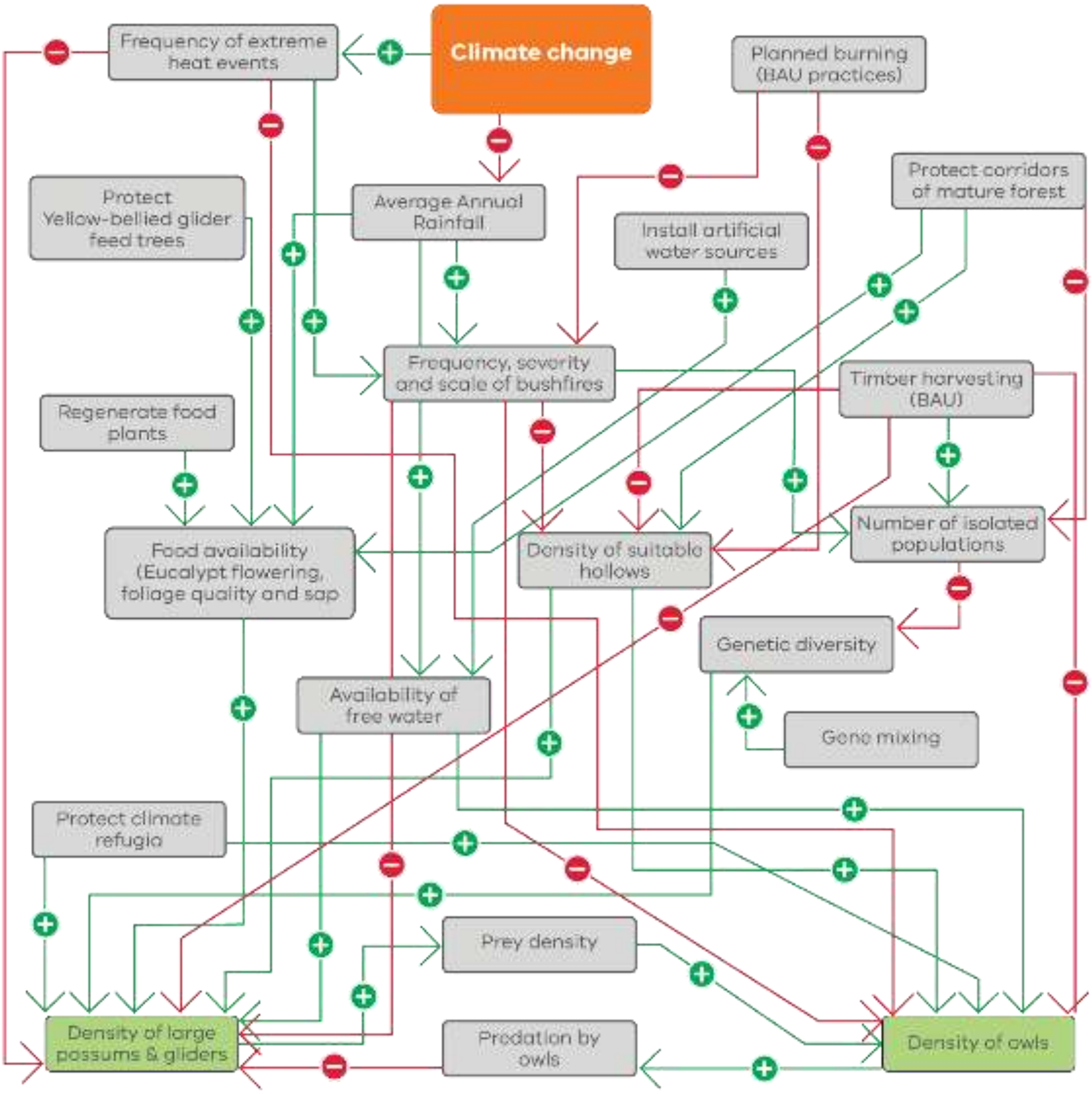

Figure 39. Best- and worst-case scenario casual model for effect of climate change on density of large possums, gliders, and owls. Diagram detail does not allow for visual representation of differences between best and worst relationships in this case. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Protect Yellow bellied glider feed trees	Food availability	0.236
1	Regenerate food plants	Food availability	0.236
1	Install artificial water sources	Availability of free water	0.236
1	Gene mixing	Genetic diversity	0.236
5	Protect climate refugia	Density of large possums and gliders	0.229
5	Protect climate refugia	Density of owls	0.229
7	Availability of free water	Density of large possums and gliders	0.013
7	Availability of free water	Density of owls	0.013
7	Number of isolated populations	Genetic diversity	0.013
10	Climate change	Frequency of extreme heat events	0.009
10	Climate change	Average annual Rainfall	0.009
10	Frequency of extreme heat events	Frequency severity and scale of bushfires	0.009
10	Frequency of extreme heat events	Density of large possums and gliders	0.009
10	Frequency of extreme heat events	Density of owls	0.009
10	Average annual Rainfall	Food availability	0.009
10	Average annual Rainfall	Frequency severity and scale of bushfires	0.009
10	Frequency severity and scale of bushfires	Density of suitable hollows	0.009
10	Frequency severity and scale of bushfires	Number of isolated populations	0.009
10	Frequency severity and scale of bushfires	Density of large possums and gliders	0.009
10	Frequency severity and scale of bushfires	Density of owls	0.009
10	Density of suitable hollows	Density of large possums and gliders	0.009
10	Density of suitable hollows	Density of owls	0.009
10	Planned burning BAU practices	Frequency severity and scale of bushfires	0.009
10	Planned burning BAU practices	Density of suitable hollows	0.009
10	Timber harvesting BAU practices	Number of isolated populations	0.009
10	Timber harvesting BAU practices	Density of large possums and gliders	0.009
10	Timber harvesting BAU practices	Density of owls	0.009
10	Genetic diversity	Density of large possums and gliders	0.009
29	Average annual Rainfall	Availability of free water	0.004
29	Food availability	Density of large possums and gliders	0.004
29	Timber harvesting BAU practices	Density of suitable hollows	0.004
29	Protect corridors of mature forest	Number of isolated populations	0.004
29	Prey density	Density of owls	0.004

Figure 40. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for climate change on density of large possums, gliders, and owls

The highest ranked links were protection of Yellow-Bellied Glider feed trees and regeneration of food plants on food availability, installation of artificial water sources on the availability of free water, and protecting climate refugia on density of large possums, gliders and owls. These links may be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.236 for the first four actions, and 0.229 for the latter two.

II. Effect of habitat loss on density of owls, hollow dependant bats and arboreal mammals

This model explores the ramifications of the loss of hollow bearing trees (HBT) as key habitat for of bats, arboreal mammals, and owls. It also incorporates potential management actions (in orange) and additional threats of burning and timber harvesting, to explore how they may impact the system. Species of interest in this model are generalisable beyond the seven species chosen for Specific Needs assessment.

Below is a combined best- and worst-case scenario for this condition followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

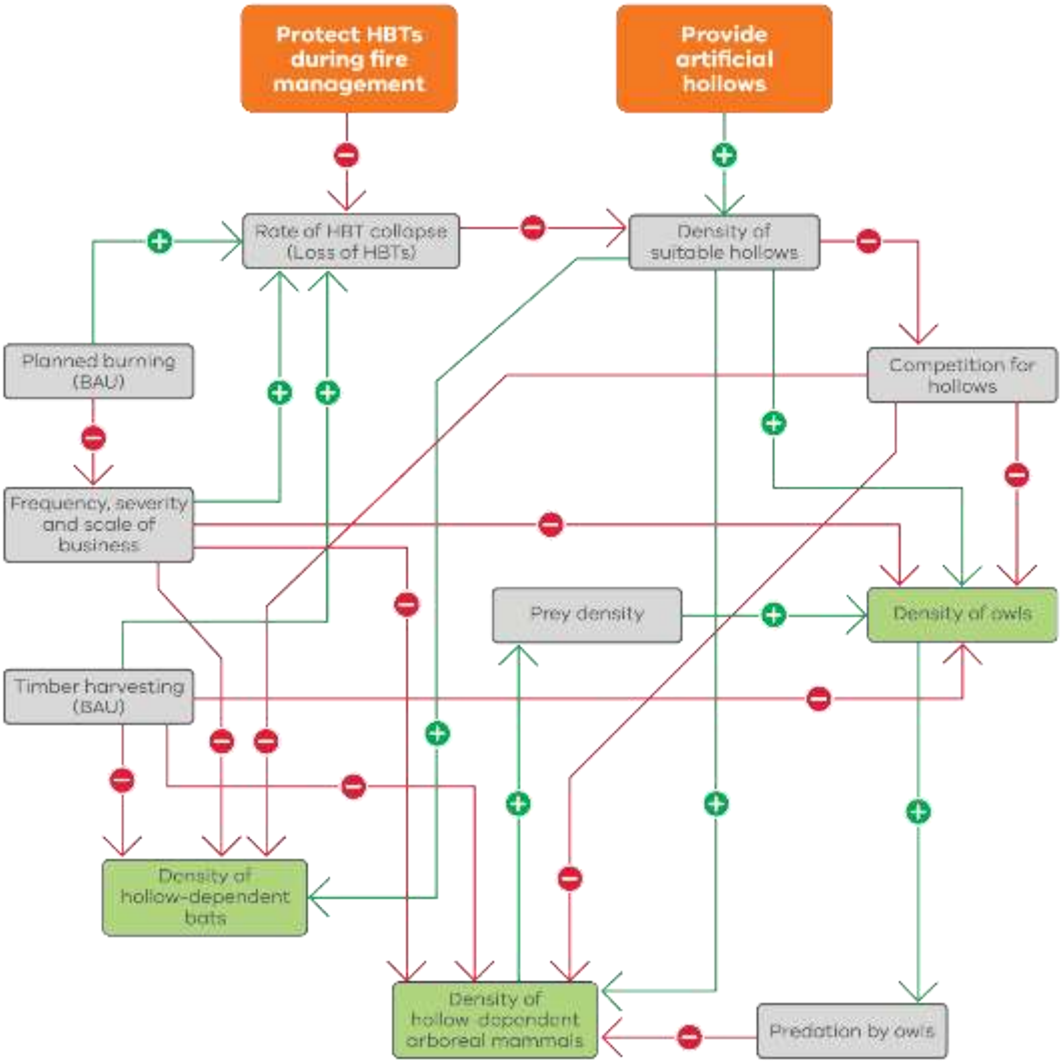

Figure 41. Best- and worst-case scenario casual model for effect of habitat loss on density of owls, hollow dependant bats, and arboreal mammals. Diagram detail does not allow for visual representation of differences between best and worst relationships in this case. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Density of owls	Predation by owls	0.356
2	Predation by owls	Density of hollow dependent arboreal mammals	0.346
3	Density of suitable hollows	Competition for hollows	0.300
3	Density of suitable hollows	Density of owls	0.300
3	Provide artificial hollows	Density of suitable hollows	0.300
6	Rate of HBT collapse Loss of HBTs	Density of suitable hollows	0.290
6	Density of suitable hollows	Density of hollow dependent bats	0.290
6	Density of suitable hollows	Density of hollow dependent arboreal mammals	0.290
9	Planned burning BAU practices	Frequency severity and scale of bushfire	0.033
10	Rate of HBT collapse Loss of HBTs	Frequency severity and scale of bushfire	0.022
10	Rate of HBT collapse Loss of HBTs	Competition for hollows	0.022
10	Rate of HBT collapse Loss of HBTs	Density of hollow dependent arboreal mammals	0.022
10	Disturbance logging	Rate of HBT collapse Loss of HBTs	0.022
10	Protect HBTs during fire management	Provide artificial hollows	0.022
10	Provide artificial hollows	Competition for hollows	0.022
10	Provide artificial hollows	Density of hollow dependent arboreal mammals	0.022
10	Competition for hollows	Density of hollow dependent arboreal mammals	0.022
10	Density of hollow dependent arboreal mammals	Density of owls	0.022
10	Prey density	Density of owls	0.022
20	Planned burning BAU practices	Competition for hollows	0.011
20	Planned burning BAU practices	Density of hollow dependent bats	0.011
20	Planned burning BAU practices	Density of hollow dependent arboreal mammals	0.011
20	Frequency severity and scale of bushfire	Rate of HBT collapse Loss of HBTs	0.011
20	Frequency severity and scale of bushfire	Protect HBTs during fire management	0.011
20	Frequency severity and scale of bushfire	Density of hollow dependent bats	0.011
20	Frequency severity and scale of bushfire	Density of hollow dependent arboreal mammals	0.011
20	Frequency severity and scale of bushfire	Density of owls	0.011
20	Rate of HBT collapse Loss of HBTs	Density of hollow dependent bats	0.011
20	Disturbance logging	Frequency severity and scale of bushfire	0.011
20	Disturbance logging	Density of hollow dependent arboreal mammals	0.011
20	Protect HBTs during fire management	Rate of HBT collapse Loss of HBTs	0.011
20	Protect HBTs during fire management	Competition for hollows	0.011
20	Protect HBTs during fire management	Density of hollow dependent bats	0.011
20	Provide artificial hollows	Density of hollow dependent bats	0.011
20	Competition for hollows	Density of hollow dependent bats	0.011
20	Competition for hollows	Density of owls	0.011
20	Density of hollow dependent bats	Prey density	0.011
20	Density of hollow dependent arboreal mammals	Prey density	0.011
20	Density of owls	Density of hollow dependent bats	0.011
20	Prey density	Density of hollow dependent arboreal mammals	0.011

Figure 42. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for habitat loss on density of owls, hollow dependant bats, and arboreal mammals

The table for this problem-response scenario depicts the ranking of uncertainties from highest to lowest (links were no uncertainty was identified aren't depicted). The highest ranked links were density of owls on predation by owls (reduction in uncertainty of 0.356), predation by owls on density of hollow dependent arboreal mammals (reduction in uncertainty of 0.346), provide artificial hollows on density of suitable hollows, rate of hollow-bearing tree collapse on density of suitable hollows (reduction in uncertainty of 0.20), and density of suitable hollows on competition for hollows (reduction in uncertainty of 0.30), density of owls (reduction in uncertainty of 0.30), density of hollow dependent bats (reduction in uncertainty of 0.29) and density of hollow dependent arboreal mammals (reduction in uncertainty of 0.29). These may be good candidates for research projects, as they represent the highest reduction in uncertainty.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 44 and 45) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Squirrel Glider (*Petaurus norfolcensis*)

A number of actions identified during workshops for arboreal mammals in general were relevant to the Squirrel Glider (i.e. provide artificial hollows, rope bridges to connect fragmented habitat). However, after consultation with a Squirrel Glider expert (Jerry Alexander, DELWP), additional actions were raised that warranted inclusion to assess their relative benefits for the persistence of this species. These actions were supported by literature and expert opinion.

Number experts: 9

Locations:

Grampians/Central and eastern Victoria

Current population in Victoria: Locations chosen for consideration during elicitations focused on the north-east distribution of the Squirrel Glider in Victoria. It was noted that records for this species fall into three broad types of landscape context:

(A) Linear strips: includes along roadsides e.g. Toolleen/Colbinabbin area, Euroa area

(B) Forest blocks: contiguous forest blocks, including along rivers e.g. Chiltern, Warby-Ovens NP, Wooragee, along Goulburn River from Arcadia to Echuca

(C) Fragmented patches within rural landscape: patches of habitat within cleared land including single trees, narrow e.g. Molyullah

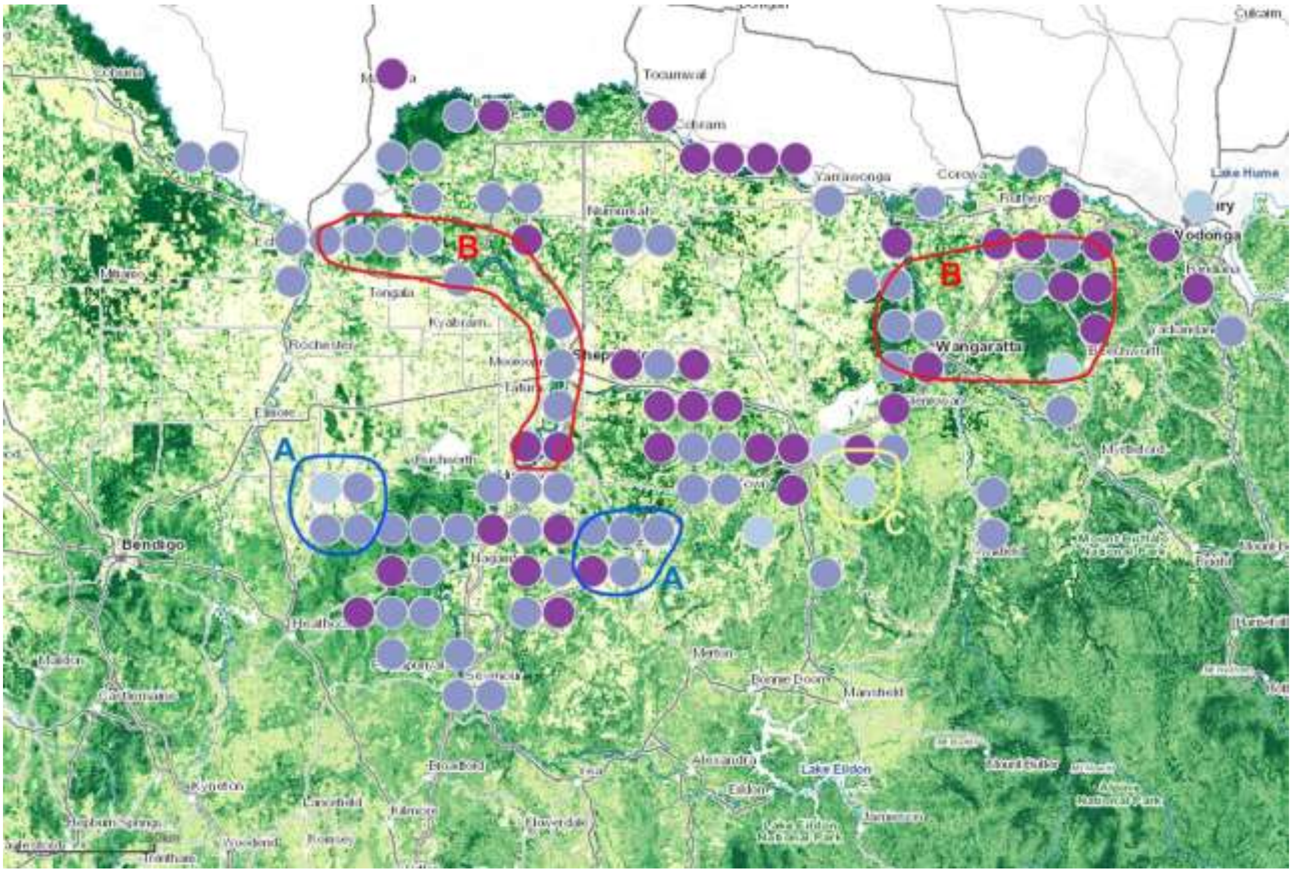

Figure 43. Locations for Squirrel Glider actions

	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Squirrel Gliders.
1 2	Exclude barbed wire on fences 25% or 50%	Removing, covering (e.g. with polypipe) or replacing the top strand of barbed wire fences will help prevent animals getting caught as they glide over (tails get wrapped around the wire, effectively trapping the animal and resulting in mortality). This entrapment of animals occurs particularly along roadside strips of habitat that are bordered by fence lines along the adjacent private land, where revegetation programs expand habitat out from roadsides, and where roads intersect.
5 3 4	Install glider poles/rope bridges 25% or 50%	Install glider poles and/or rope bridges where current fragmentation occurs between existing habitat and over large roads, and where new freeway construction occurs e.g. Shepparton bypass through existing forest, to create connectivity where movement structure is absent. Recent research has shown that Squirrel Gliders use canopy bridges and glider poles to move along and crossroads (e.g. Soanes et al. Wildlife Research 2015). It is anticipated that installing such structures would increase access to resources among fragmented habitat. Research has also shown that such structures can have a positive impact on gene flow for this species (e.g. Soanes et al. Journal of Applied Ecology 2017).
6	Install artificial hollows	Provide artificial hollows (nest boxes or chainsaw hollows) for denning, breeding etc. in areas where natural hollows are lacking. This includes areas subject to a disturbance (e.g. bushfire or areas subject to timber harvesting) or in areas with a decline in natural hollows (e.g. natural collapse of stags). The exact design and density of these is to be specified, but hollows will be installed based on the best available knowledge at the time. Prior to installation, factors to be considered include hollow design, density, position, maintenance and monitoring.".
7	Install artificial hollows + expand habitat along linear strips	As per install artificial hollows, in conjunction with increasing the width of linear strips by extending fencing out (~40m) (into cleared private land) parallel to the existing linear reserve and relying on seed fall for natural regeneration to occur, increasing potential foraging habitat (i.e. lerps, manna, honeydew) quickly, without the need to plant additional trees.
8	Protect hollow-bearing trees during fire management	Increase protection measures for hollow-bearing trees during fire management (planned burning and fire suppression), including hazardous tree removal. This may include a review of current procedures, consideration of species-specific protection measures, and improving on-ground implementation. This action would raise the priority of protection of hollow-bearing trees and ensure protection actions for these trees were undertaken in a more coordinated way across all fire districts.

Based on expert assessment the benefit of each action at each location for this species is as follows:

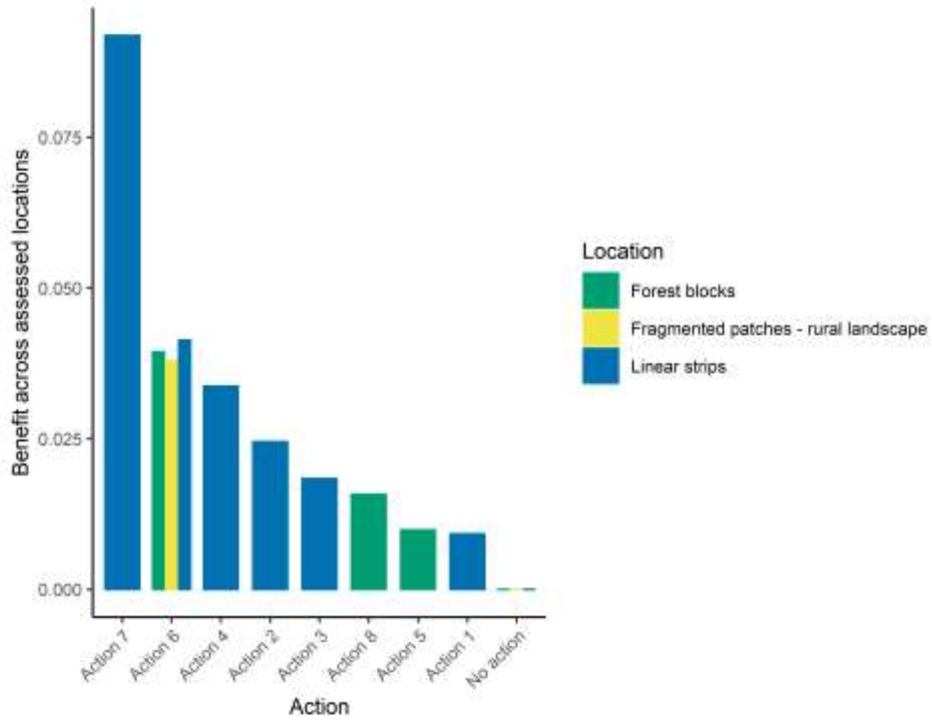

Figure 44. Benefit of each action/location combination to the Squirrel Glider overall persistence probability across all assessed locations.

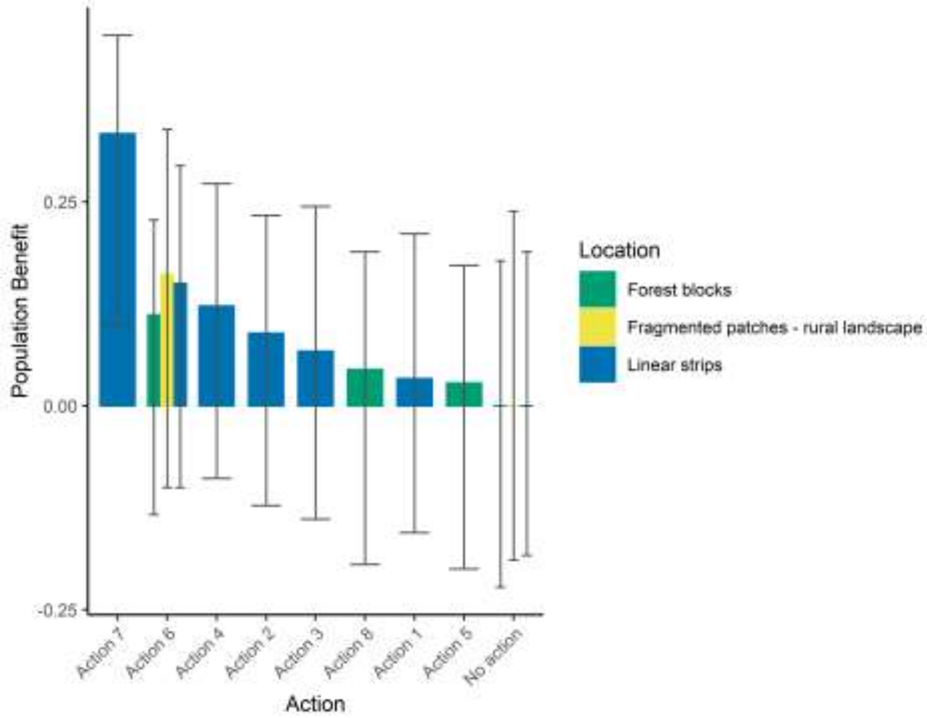

Figure 45. Mean change in Squirrel Glider probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Results for this species show a clear preference for most beneficial action. In locations representing linear strips along roadsides, installing artificial hollows in conjunction with increasing the width of linear strips by extending fencing out (~40m) parallel to the existing linear reserve is considered by far the best choice. It is expected that natural regeneration will occur in this space resulting in ongoing habitat creation. Simply install artificial hollows, however, also demonstrates some benefit, and can be applied to any location.

Species: Southern Greater Glider (*Petauroides volans*)

Many of the actions proposed at the workshop were focused on this species, so taxon leads needed to balance a good selection of actions with an appropriate number of locations, to avoid asking the experts to fill in too many scenarios. Actions selected address threats relating to the loss of hollow-bearing trees, the loss of genetic diversity and the lack of free water during extreme heat events/drought likely to increase under climate change. Taxon leads felt that these actions covered a suite of actions previously proposed for this species, either through the Action Statement or by the community/other organisations. Some actions, such as ‘installation of artificial hollows’, have already been trialled by some organisations (e.g. Greening Australia) and are also the focus of federal bushfire funding for the species (e.g. Wildlife and Habitat Bushfire Recovery Program).

Number of experts: 12

Locations:

North East RFA, Central Highlands RFA, Gippsland RFA, East Gippsland RFA

Current population in Victoria: This species is patchy in abundance and has declined across its range but is still very widely distributed across Victoria. Locations were chosen that covered most known populations and selected four Regional Forest Agreement (RFA) Areas. This decision was also centred on trying to include many of the connected populations of Southern Greater Gliders in continuous forest through eastern Victoria.

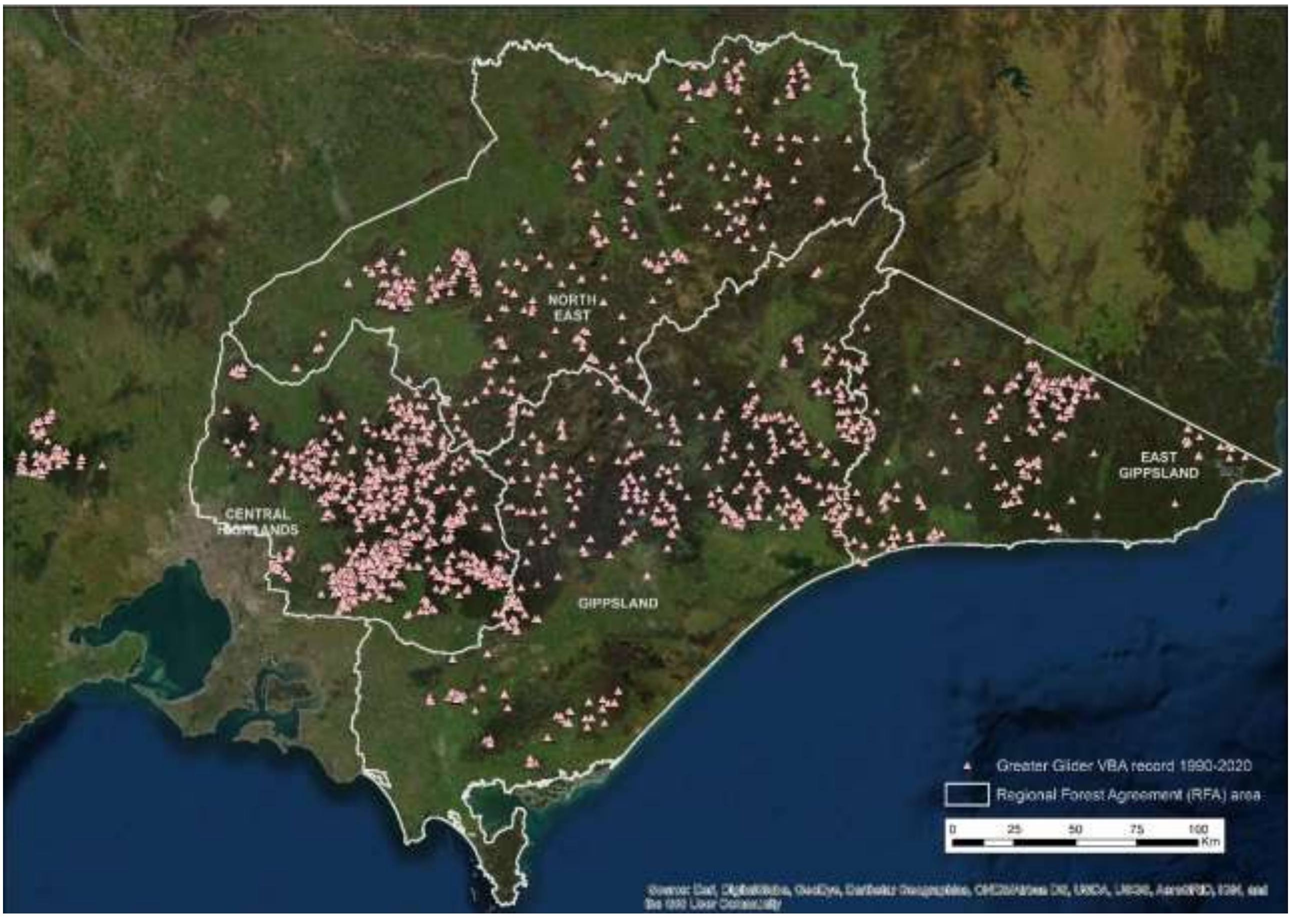

Figure 46. Locations for version 1 Southern Greater Glider actions

#	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Greater Gliders.
1	Protect hollow-bearing trees during fire management	Increase protection measures for hollow-bearing trees during fire management (planned burning and fire suppression), including hazardous tree removal. This may include a review of current procedures, consideration of species-specific protection measures, and improving on-ground implementation. This action would raise the priority of protection of hollow-bearing trees and ensure protection actions for these trees were undertaken in a more coordinated way across all fire districts.
2 3	Install artificial hollows 5% or 25% of potential habitat	Provide artificial hollows (nest boxes or chainsaw hollows) for denning, breeding etc. in areas where natural hollows are lacking. This includes areas subject to a disturbance (e.g. bushfire or areas subject to timber harvesting) or in areas with a decline in natural hollows (e.g. natural collapse of stags). Imagine this action happening at 5% or 25% of potential habitat of the target species where hollows are lacking. Note: The exact design and density of these is to be specified, but hollows will be installed based on the best available knowledge at the time. Prior to installation, factors to be considered include hollow design, density, position, maintenance and monitoring.
4 5	Install artificial hollows + provide artificial water sources 5% or 25% of potential habitat	As above at 5% or 25% of areas, but with the addition of artificial water sources (supplementary water) at the same sites. Note: this has not been trialled and would require research to test if access to free water was an issue for these populations. Supplementary rate of water provision is to be specified but is potentially once per week during certain seasons.
6	Gene mixing	Increase connectivity between isolated populations through gene mixing. Gene mixing involves ad hoc wild-to-wild translocations of gliders from one population, to another population within their current Victorian range. Note: The current understanding of this action is limited by insufficient information on the genetic profile of different greater glider populations. Genetic data would need to be collected prior to this action occurring. Augmented gene flow through gene mixing would only be undertaken for populations that are isolated and that have clear evidence of a loss of genetic diversity. An example of locations where you might expect this to be the case are those in South Gippsland, where patches of forest are highly fragmented (e.g. Mirboo North, Mullungdung). The supplementary rate of animals and the source population would be specified in the future, with input from conservation geneticists about the best approach.

Based on expert assessment the benefit of each action at each location for this species is as follows:

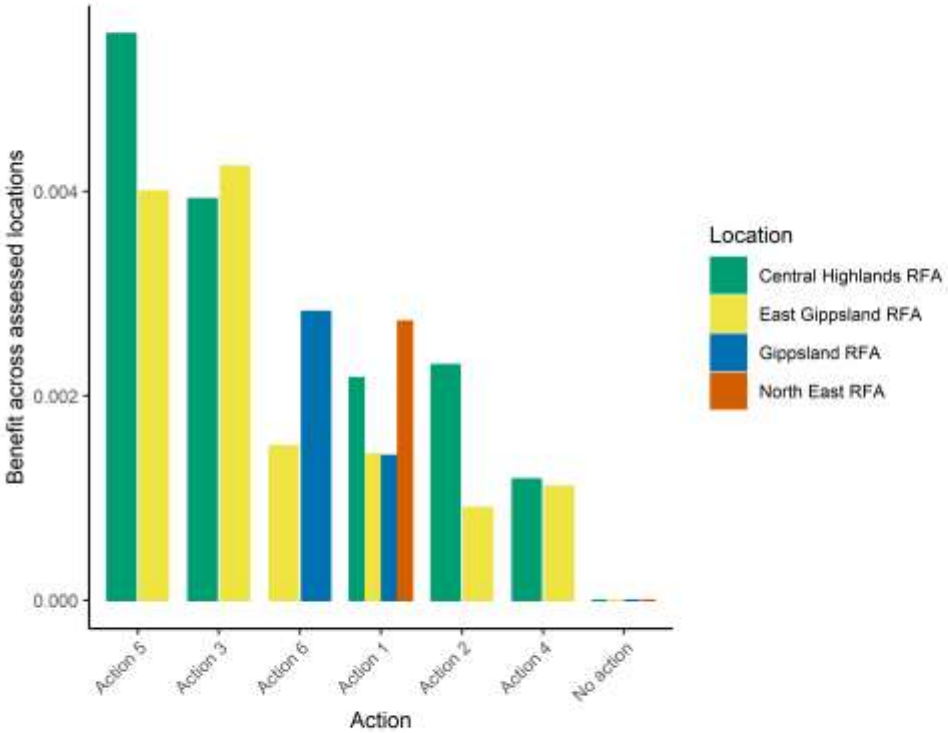

Figure 47. Benefit of each action/location combination to the Southern Greater Glider overall persistence probability across all assessed locations.

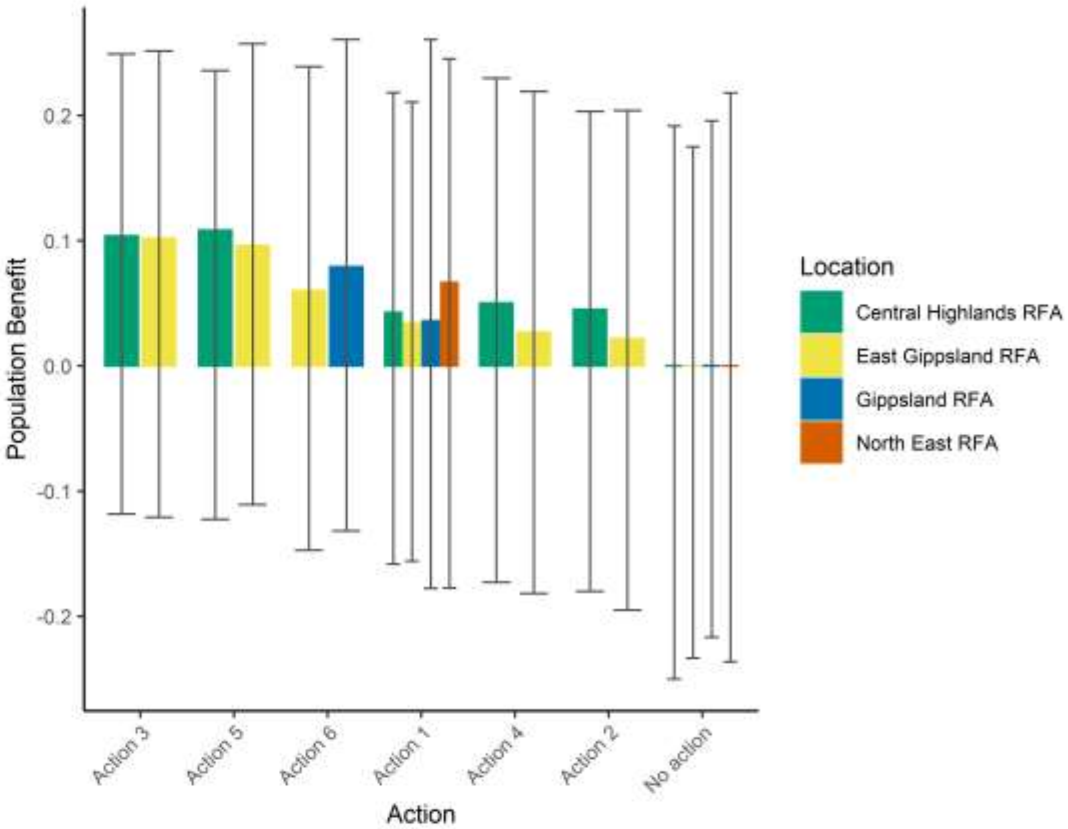

Figure 48. Mean change in Southern Greater Glider probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

During the expert elicitation workshop some experts raised concerns about the locations chosen and observed that given the definition of 'persistence', it was unlikely that there would be much differentiation between RFA areas in scoring (especially in the upper bounds of the confidence intervals) because they were such large areas. However, there were no particular suggestions proposed for how to prioritise particular populations or locations, and the group conceded that this would be a difficult task.

Once taxon leads had received some initial results from experts, they noted some minor variation in scoring but that this was probably not sufficient to compare between locations. Looking at these results and combining these with the comments received during the workshop, they decided a rethink of the locations for this species was warranted, with the aim of providing greater differentiation between the value of doing the actions compared with doing nothing ('no action').

Taxon leads returned to the step of defining the locations to be considered for Southern Greater Gliders, aiming to nominate more localised areas (below) that would help the elicitation process 'tease out' the relative benefit differences in expert opinion.

Locations:

Toolangi State Forest

This location is representative of locations in the Central Highlands that have high levels of disturbance. Clearfell timber harvesting occurs in this area and the location was burnt in the 2009 Black Saturday bushfires. The forest type is a mixture of the EVCs Wet Forest, Damp Forest, and Cool Temperate Rainforest.

Mirboo North

This location is representative of locations in Gippsland that are highly fragmented. Pine plantation and cleared land surround fragmented pockets of remnant vegetation through this landscape. The forest type is a mixture of the EVCs Wet Forest, Damp Forest, and Lowland Forest.

Deptford-Brookville

This location is representative of locations in East Gippsland that have high levels of disturbance and were recently burnt in the 2019/20 bushfires. There has been past and current timber harvesting in this area. The forest type is a mixture of several EVCs, the key ones being Wet Forest, Damp Forest, and Shrubby Dry Forest.

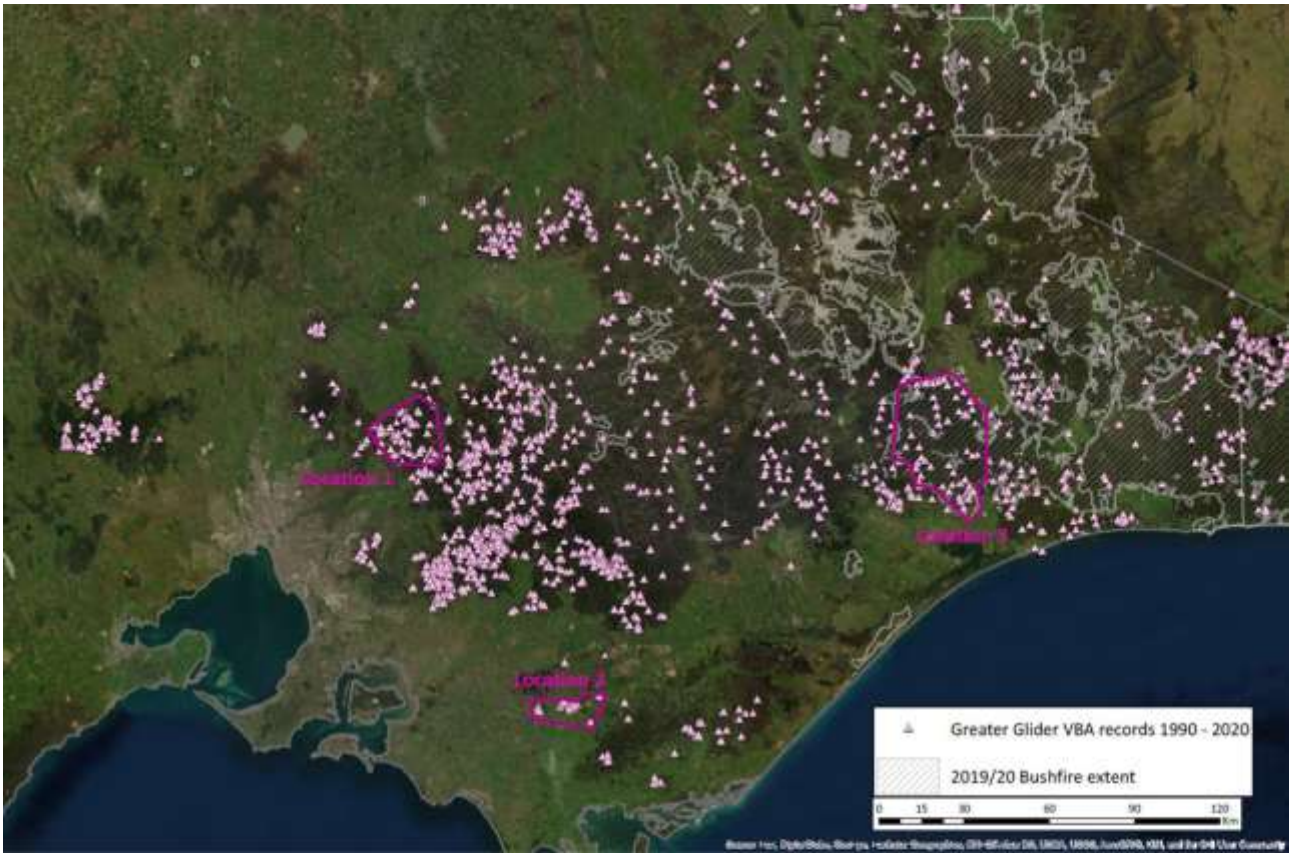

Figure 49. Locations for version 2 Southern Greater Glider actions

#	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Southern Greater Gliders.
 1 2	Install artificial hollows 10 sites 50 sites	Provide artificial hollows (nestboxes or chainsaw hollows) for denning, breeding etc. in areas where natural hollows are lacking. This includes areas subject to a disturbance (e.g. bushfire or areas subject to timber harvesting) or in areas with a decline in natural hollows (e.g. natural collapse of stags).
 3 4	Install artificial hollows + provide artificial water sources 10 sites 50 sites	As above + Install artificial water sources (supplementary water).

Based on expert assessment the benefit of each action at each location for this species is as follows:

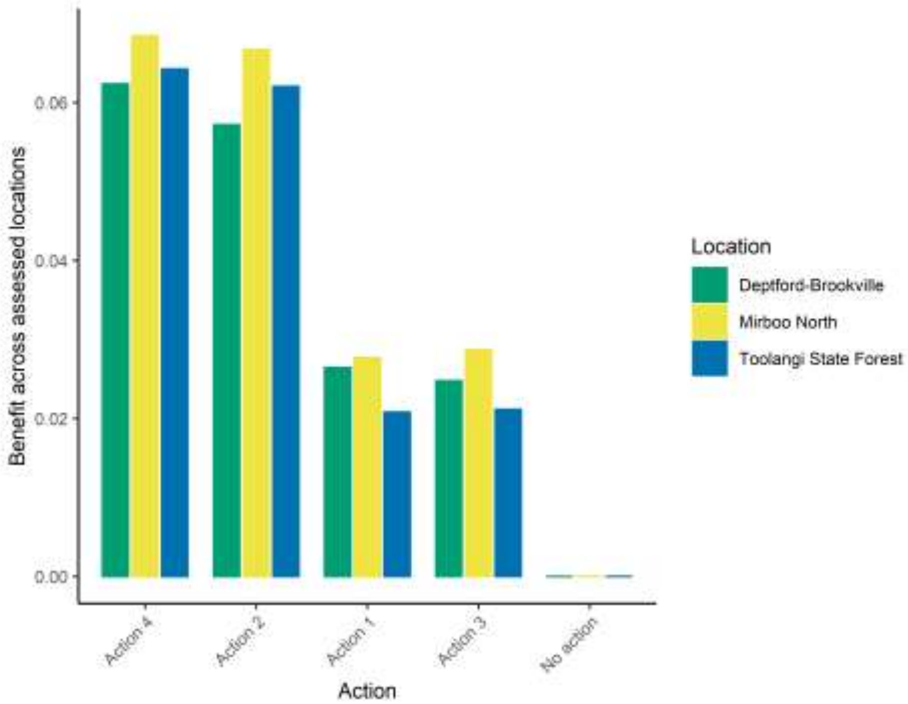

Figure 50. Benefit of each action/location combination to the Southern Greater Glider overall persistence probability across all assessed locations.

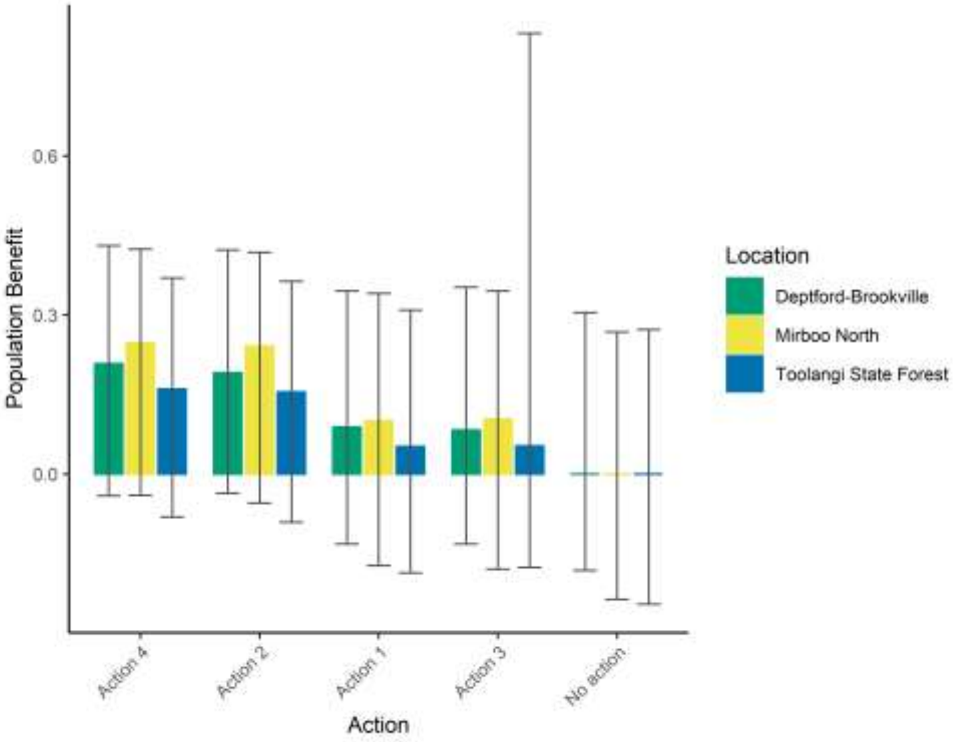

Figure 51. Mean change in Southern Greater Glider probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

In this final iteration of elicitation, actions 4 and 2 display the highest benefit values across all locations. This is consistent with a higher level of effort compared to actions 3 and 1 in the respective management technique. Overall, providing supplementary water does not appear to have a large additional benefit on top of installing artificial hollows.

Species: Barking Owl (*Ninox connivens)*

The management actions identified for threatened owls centred around management of prey species, protecting owl roost and nest sites, and possibly gene mixing. After short-listing the Barking Owl as a focal species, taxon leads consulted a Victorian Barking Owl expert (Natasha Schedvin, DELWP) and considered a range of actions, most of which are proposed in the unpublished draft update to the Barking Owl Action Statement. These were refined through group discussions; some were considered out-of-scope or unsuitable for the Specific Needs process, and we converged on two key actions. During the expert elicitation workshop, one of the participants suggested an additional management action that had not yet been suggested. This was incorporated in the elicitation process, resulting in the consideration of three key management actions.

Number of experts: 5

Locations:

North East Victoria, Central Victoria

Current population in Victoria: Owls are territorial but are wide-ranging over large areas, and so large, landscape-scale management units were considered more appropriate than small or medium-sized areas. Ahead of the elicitation workshop, three broad areas were nominated: north east Victoria, central Victoria, and the East Gippsland lowlands. However, discussion among taxon experts during the workshop led to general agreement that many Barking Owl records on the VBA, which had guided the decision to include East Gippsland, were likely erroneous and Barking Owl is highly unlikely to occur there. Therefore, the areas included for consideration for Barking Owls were limited to north east Victoria and central Victoria only.

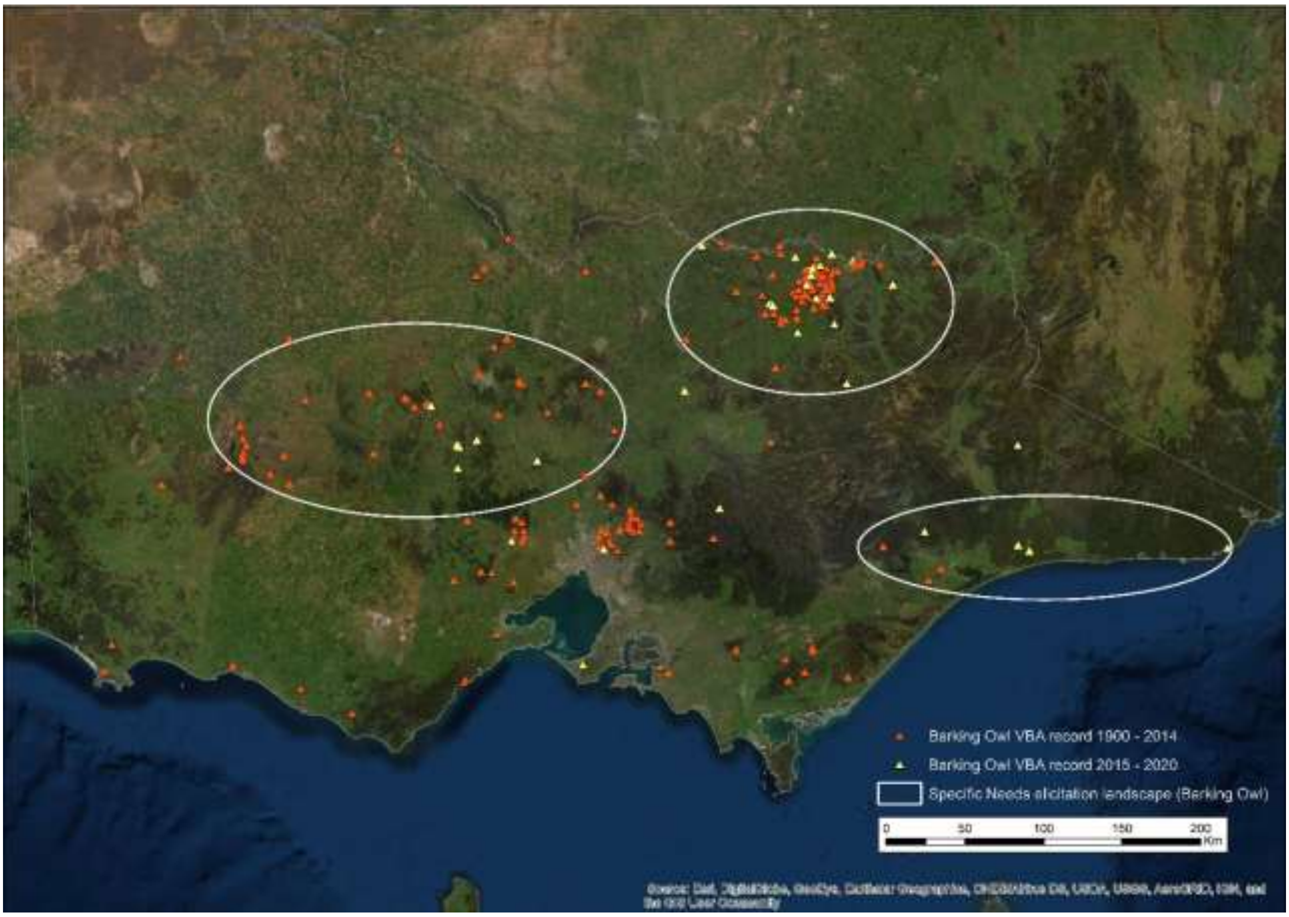

Figure 52. Locations for Barking Owl actions (noting East Gippsland lowlands has been removed from analysis)

The management actions identified as potentially suitable for consideration for threatened owls centred around management of prey species, protecting owl roost and nest sites, and possibly gene mixing.

#	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Barking Owls.
1 2	Install artificial hollows to support prey species 5% or 25% of potential habitat	Provide artificial hollows (either nest boxes or chainsaw hollows) in areas recovering from disturbance or where natural hollows are lacking. Artificial hollows may be designed to target occupancy by Barking Owl prey (i.e. entrance sizes suitable for important prey species such as Sugar Gliders, Squirrel Gliders, parrots or Eastern Ring-tailed Possums). Intended to supplement and increase hollow availability, thus increasing the abundance of Barking Owl prey species. Imagine this action being implemented at 5% or 25% of potential habitat in this location. Note: The exact design and density of artificial hollows is to be specified and will be based on the best available knowledge at the time. Prior to installation, factors to be considered include design, density, position, maintenance and monitoring.
3	Protect hollow-bearing trees during fire management	Increase protection measures for hollow-bearing trees during fire management (planned burning and fire suppression), including hazardous tree removal. This may include a review of current procedures, consideration of species-specific protection measures, and improving on-ground implementation. This action would raise the priority of protection of hollow-bearing trees and ensure protection actions for these trees were undertaken in a more coordinated way across all fire districts.
4	Install tree bands to prevent predation by lace monitors	There is evidence of nest predation by lace monitors in NSW. To counter this potential impact in Victoria, tree bands will be added to known nest trees to prevent access by monitors.

Based on expert assessment the benefit of each action at each location for this species is as follows:

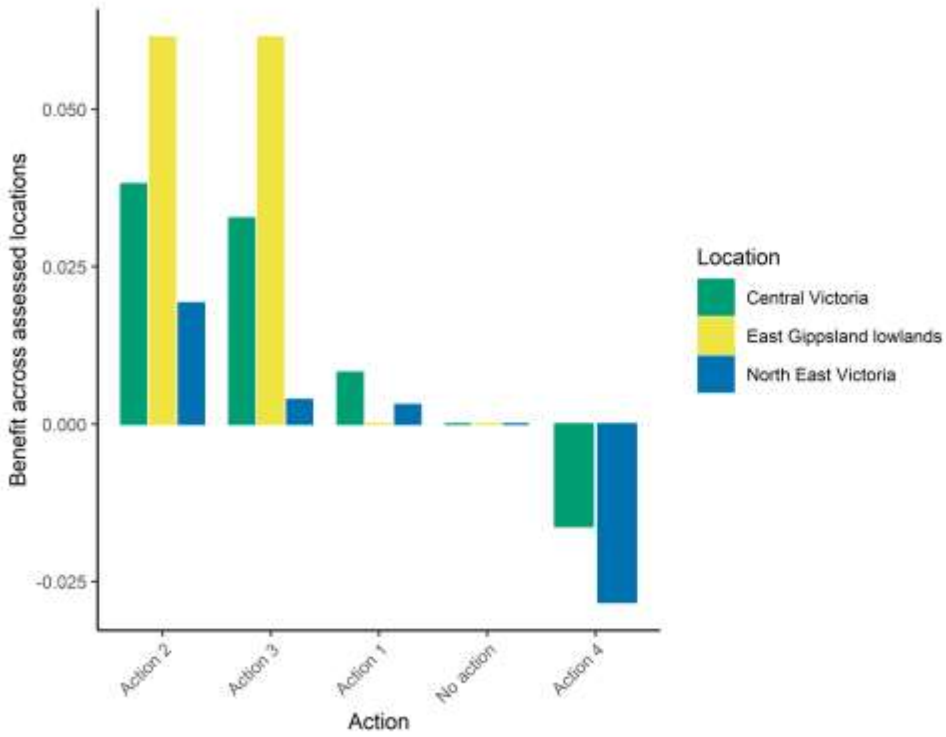

Figure 53. Benefit of each action/location combination to the Barking Owl overall persistence probability across all assessed locations.

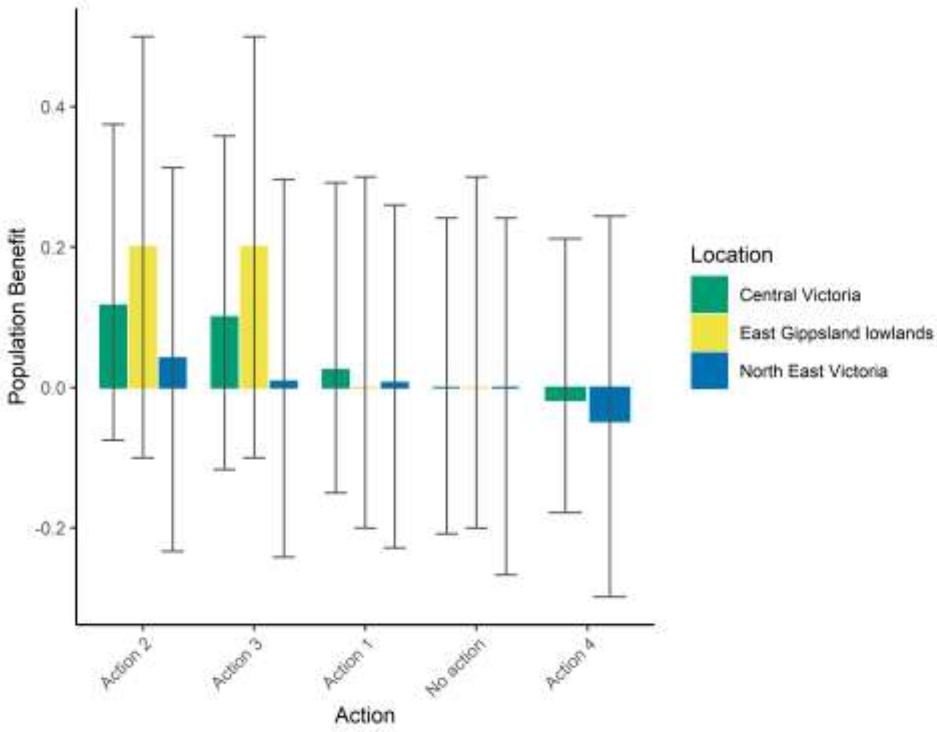

Figure 54. Mean change in Barking Owl probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Species: Masked Owl (*Tyto novaehollandiae)*

Management actions suitable for threatened owls centred around management of prey species, protecting owl roost and nest sites, and potentially considering gene mixing. Experts noted that the Masked Owl stands out as being much less abundant than other large forest-dependent owl species. Because owls are apex predators, occur at naturally low densities across the landscape, and are mobile with large home ranges, deciding on meaningful, within-scope actions and scenarios for the Specific Needs elicitation was challenging. Leads ruled out one of the actions used in the Barking Owl elicitation, the provision of artificial hollows to support prey, because the prey base of Masked Owl is predominately terrestrial. Instead an action of providing artificial hollows was retained, targeted towards use by the Masked Owls themselves.

Number of experts: 10

Locations:

East Gippsland RFA, Gippsland RFA., Central Highlands RFA, West RFA

Current population in Victoria: Contemporary records of Masked Owl are scattered across lowland forest areas in the south of Victoria, from the South Australian border to the NSW border. For this reason, and because Masked Owls are mobile and wide-ranging, four broad areas were considered during elicitation. Experts were not asked to assess the benefit of installing tree guards to prevent lace monitor predation in the West RFA, as lace monitors do not occur in the southern parts of the West RFA where Masked Owls are found.

Figure 55. Locations for Masked Owl actions

#	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Masked Owls.
1 2	Install artificial hollows 5% or 25% of potential habitat	Provide artificial hollows (nest boxes or chainsaw hollows) for denning, breeding etc. in areas where natural hollows are lacking. This includes areas subject to a disturbance (e.g. bushfire or areas subject to timber harvesting) or in areas with a decline in natural hollows (e.g. natural collapse of stags). Imagine this action being implemented at 5% or 25% of potential habitat in this location. Note: The exact design and density of these is to be specified, but hollows will be installed based on the best available knowledge at the time. Prior to installation, factors to be considered include hollow design, density, position, maintenance and monitoring.
3	Protect hollow-bearing trees during fire management	Increase protection measures for hollow-bearing trees during fire management (planned burning and fire suppression), including hazardous tree removal. This may include a review of current procedures, consideration of species-specific protection measures, and improving on-ground implementation. This action would raise the priority of protection of hollow-bearing trees and ensure protection actions for these trees were undertaken in a more coordinated way across all fire districts.
4	Install tree bands to prevent	Known Masked Owl nest trees will be banded to prevent access by potential nest predators, i.e. lace monitors

	predation by lace monitors	

Based on expert assessment the benefit of each action at each location for this species is as follows:

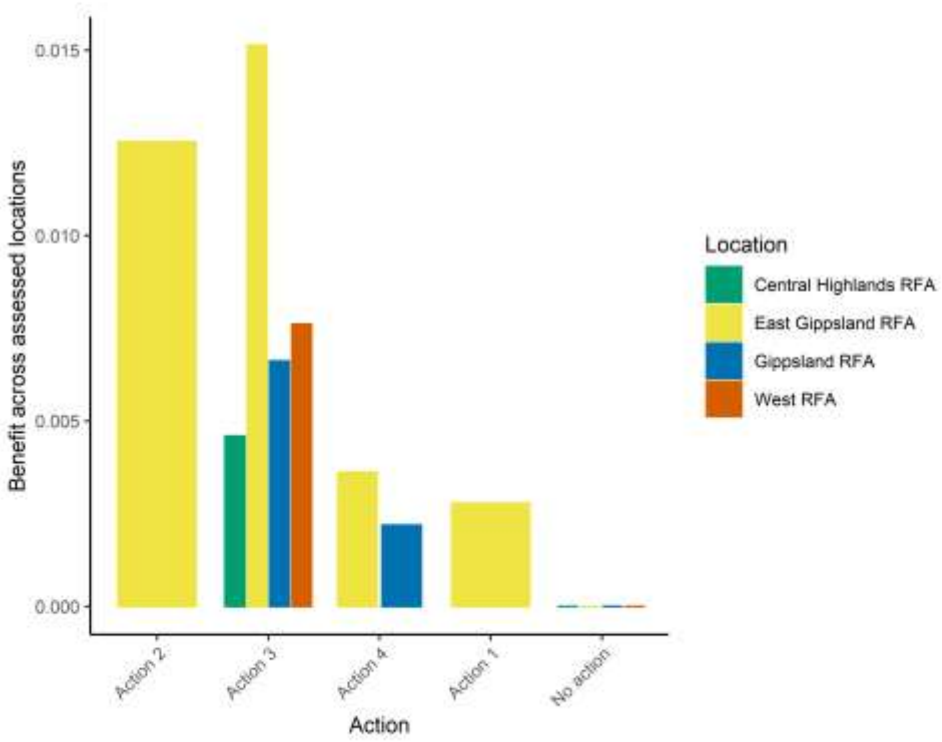

Figure 56. Benefit of each action/location combination to the Masked Owl overall persistence probability across all assessed locations.

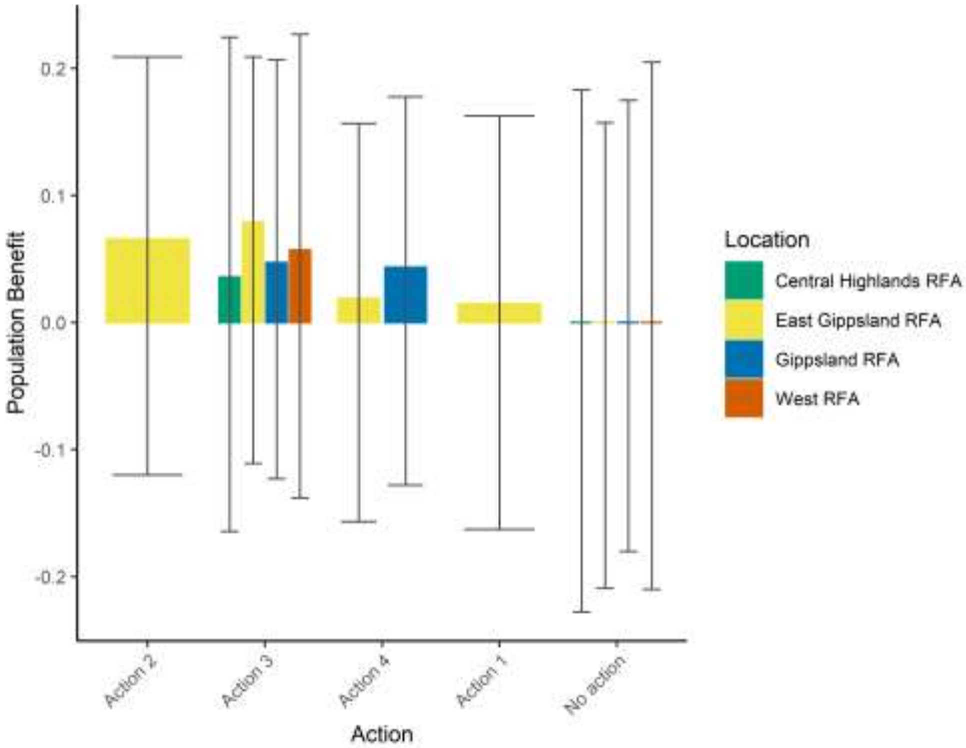

Figure 57. Mean change in Masked Owl probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Benefits of the proposed actions for this species show a large degree of contention between experts. However, this contention is fairly consistent across actions. In the region with the highest concentration of populations, East Gippsland, the greatest benefit is seen from installing artificial habitats across 25% of suitable sites. This demonstrates a substantially higher benefit than the same action at 5% of sites. Protecting hollow-bearing trees during fire management is the only action to show expected benefit across all locations. Installing tree bands to protect from lace monitors shows a negative benefit as experts assessed the probability of persistence under a no action scenario as higher than under this management action scenario.

Species: Eastern Bent-Wing Bat *(Miniopterus orianae oceanensis)*

The Eastern Bent-Wing Bat roosts primarily in caves and mines, but also in coastal cliff rock crevices, stormwater drains and culverts, and in human-made tunnels. It is distributed from the Otway Ranges in the west across most of eastern Victoria. There is only one known maternity cave in Victoria, which is located in East Gippsland in the Nargun Cave. As the most critical location for the species in Victoria, this was selected as one of the locations for this assessment. Only females go to the maternity cave, with births occurring over summer. Outside the breeding season, the females and their young disperse to many non-breeding roosts spread across eastern Victoria, up to 200-300 km away. Most roost sites in central Victoria are in disused mines from the gold mining era (e.g. mid-late 1800s). The Christmas Hills and Eildon areas were used as the second location, representing non-breeding roosts in mines.

Mating is most likely to occur at the non-breeding sites, where the males typically remain year-round, although there is likely to be some movement between roosts within localised areas. It is not known however, how much interchange there is between different regions. It is possible that the bats use the same non-breeding caves each year and therefore breed within the same group. If there is little mixing, each localised group (subpopulation) may have variation within their genetic make-up.

The current Victorian population size is estimated to be approximately 48,000 (potential range 30,000 to 70,000), of which approximately 30,000 adult and first year females congregate at the maternity cave. In contrast, the number of individuals in the Christmas Hills/Eildon areas is likely to be in the vicinity of 1,000 – 3,000 individuals (males and females).

Number of experts: 10

Locations: Nargun Cave

Current population in Victoria: The 2019/20 bushfires burnt to within approximately 10 km of the Nargun Cave. This occurred during the breeding season when the entire reproductive female population of Victorian Eastern Bent-Wing Bats and newborn young were present. If large quantities of smoke had been drawn into the cave during this period, there could have been devastating consequences. The full impact of the fires is unknown, however, there was at least some successful breeding.

Cave bats generally do not tolerate human disturbance while they are roosting during the day. Whilst Nargun Cave has been successfully managed in the past to reduce visitors, e.g. blocking access tracks, recently tracks have been illegally opened and more people have been visiting the cave. In addition to the disturbance caused, visitors may inadvertently introduce the highly virulent and fatal fungus that causes White-nose Syndrome. White-nose Syndrome has killed many millions of cave-roosting bats in North America. It is currently believed to be absent from Australia, however, a recent risk assessment concluded that it was 'very likely/ almost certain' to be introduced to Australia within the next ten years and "likely" that Australian bats would be exposed to it. The Eastern Bent-Wing Bat and Eastern Horseshoe Bat were two of the species that were likely to be impacted (Holz et al. 2019). If it were to be introduced, then the movements of bats between caves would cause rapid spread of the disease throughout the populations, resulting in significant declines.

Periodic cat predation has been observed at the small entrance to Nargun Cave, with large numbers of bats taken in some years. It appears that individual cats learn the art of catching bats as they emerge.

Many of the mines used as key non-breeding roosts in the Eildon/Christmas Hills area are at risk of partial or complete collapse as they are 100-150 years old. The loss of these sites would significantly reduce available roosts for males year-round and females during the non-breeding season, as there are no natural caves in these areas. In addition, some mines are being closed permanently due to safety concerns.

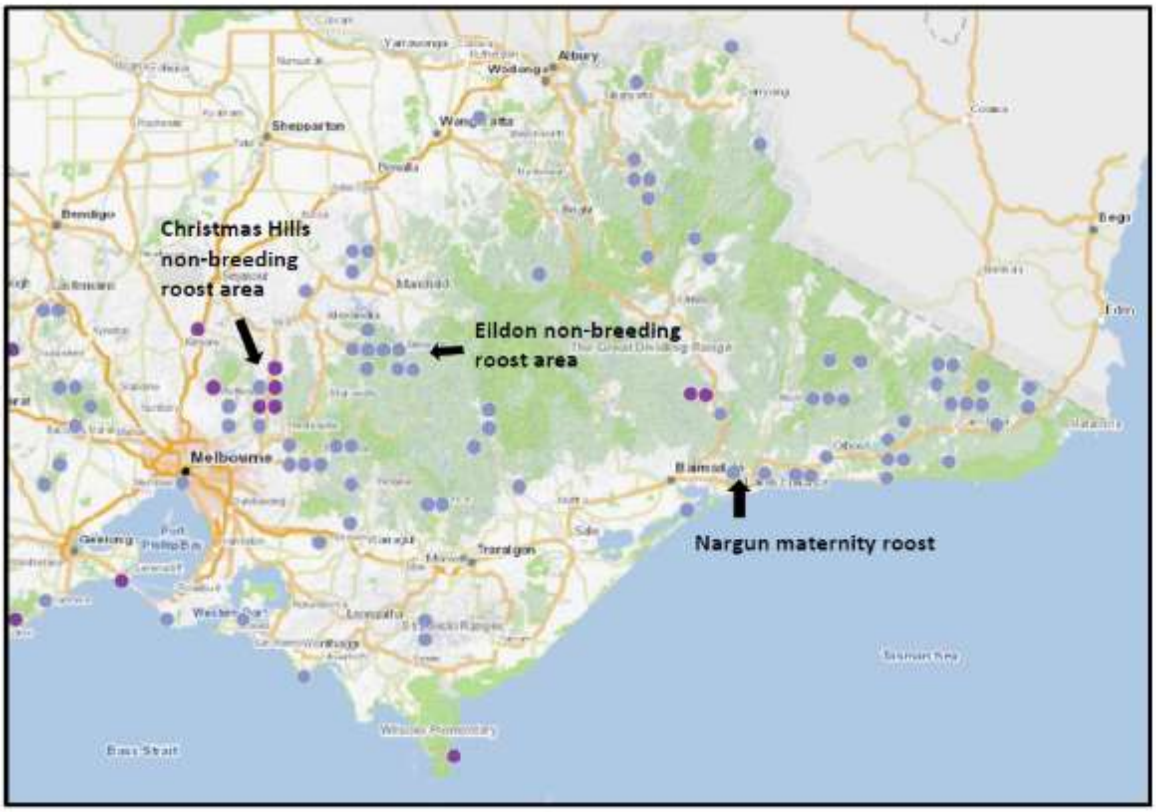

Figure 58. Eastern Bent-Wing Bat locations

#	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Bats.
1	Prevent human disturbance	Prevention of human disturbance at roost sites.
2	Biosecurity protocols	Develop and implement stringent biosecurity protocols to reduce the risk of introduction of White-nose Syndrome.
3	Gene mixing	
4	Protection from future fire	Identify this species and the Nargun Cave as a high priority asset in fire planning and management and undertake active targeted preventative actions.
5	Predator control	Targeted, localised control of introduced predators (cats and foxes).
6	Mine roost protection/ repair	Stabilise or repair key disused mine roosts to prevent collapsing.

Based on expert assessment the benefit of each action at each location for this species is as follows:

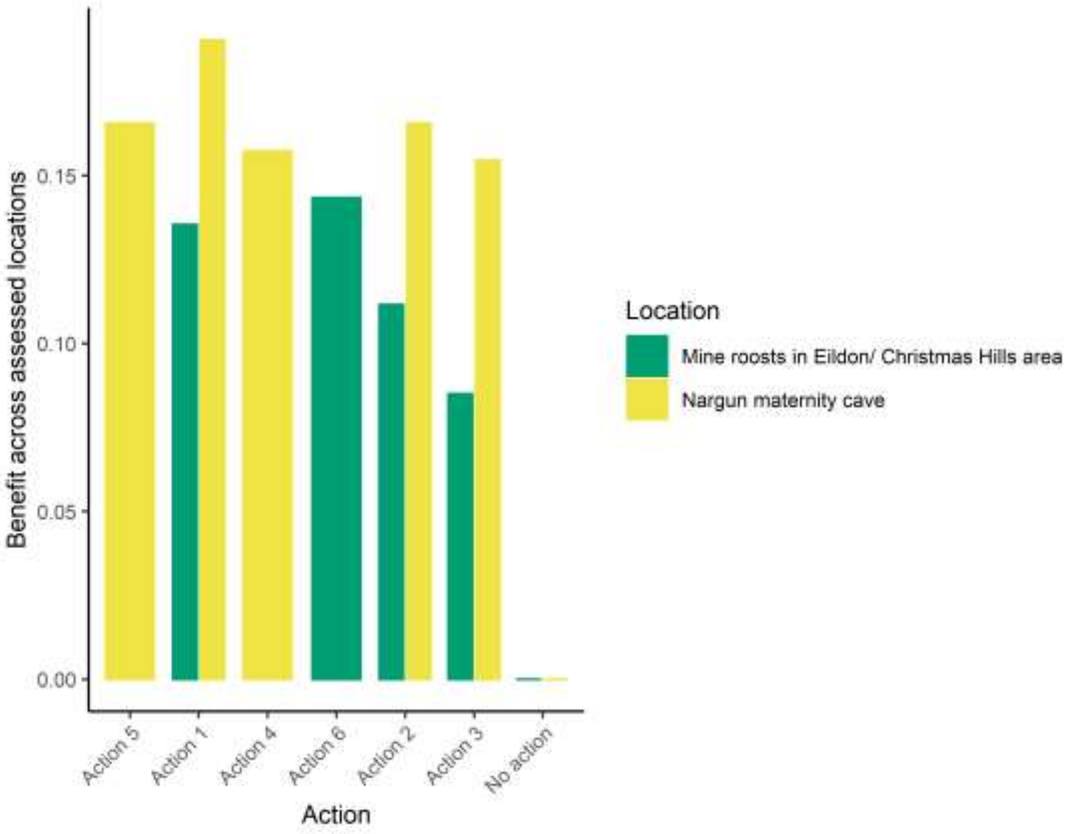

Figure 59. Benefit of each action/location combination to the Eastern Bent-Wing Bat overall persistence probability across all assessed locations.

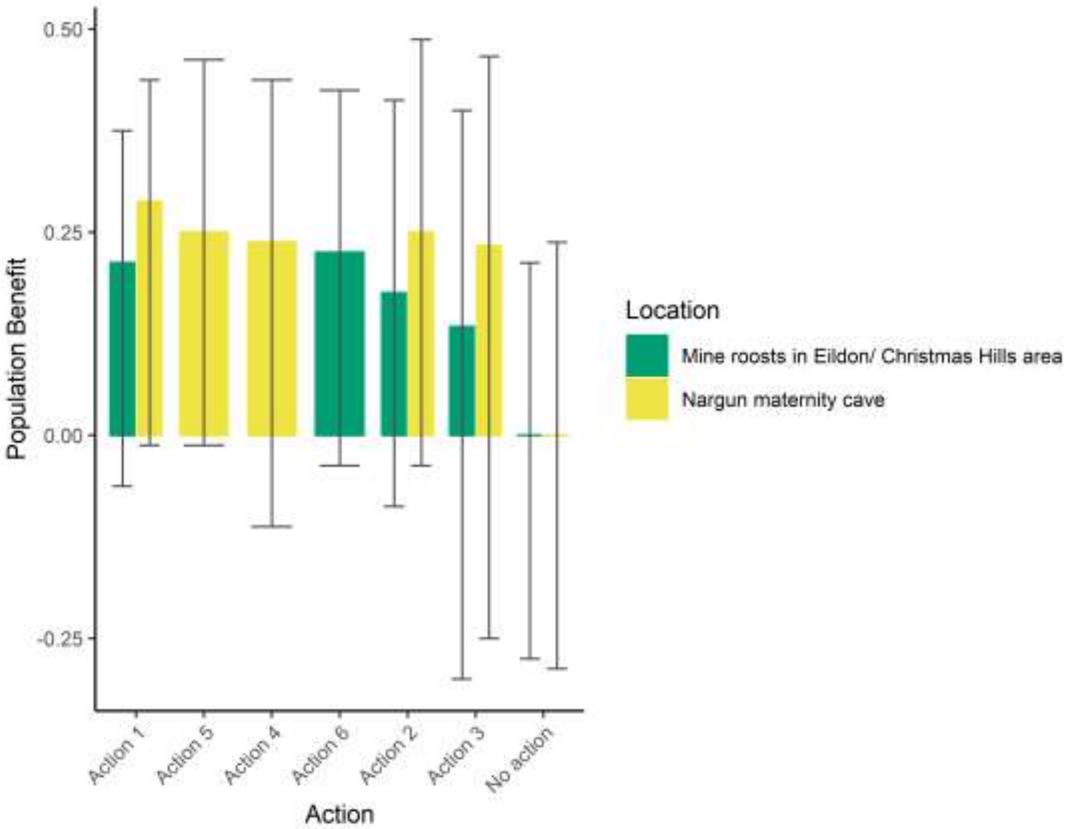

Figure 60. Mean change in Eastern Bent-Wing Bat probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

All actions for this species display a similar expected benefit, with actions predicted to be more successful at the maternity cave compared to mine roosts when both are applicable. Overall, the most beneficial actions are predator control and prevention of human disturbance, suggesting actions already being undertaken and should be sustained or strengthened.

Species: Eastern Horseshoe Bat *(Rhinolophus megaphyllus)*

There are two main subpopulations of Eastern Horseshoe Bats, one in Gippsland encompassing an area from Bairnsdale, Lakes Entrance, Buchan to Mallacoota, the second is in the Eastern Highlands in the Christmas Hills, Warburton, Eildon and Strathbogie areas. There are three known maternity sites in East Gippsland, with the largest colony being 2000-6000 individuals at the Nargun Cave, in the same cave as the maternity site for Eastern Bent-wing Bats.

In contrast the largest colony found to date in the Eastern Highlands is 40 individuals. No maternity roosts have yet been found in the Eastern Highlands, however heavily pregnant females have been recorded in the Eildon area, 200 km from the closest known maternity site in East Gippsland. This distance is considered too far for this slow-flying species to migrate while heavily pregnant. It is therefore assumed that there is a maternity roost within a disused mine somewhere within the Eastern Highlands, but it has not yet been found. This population may now be genetically isolated from the main population in East Gippsland, and given the small numbers, genetic variation may be, or become, low.

Little is known of the current status or population trends of this species. The total Victorian population is considered to be less than 7,500 individuals, and it is likely to have declined in recent decades.

The threats are the same as for the Eastern Bent-Wing Bat, and the same general locations are used. Within the Eildon and Christmas Hills area, different mines are sometimes used to the Eastern Bent-Wing Bat but they are in the same general area, and have the same, if not more, risk of collapse, as they are often smaller mines.

Number of experts: 10

Locations:

Current population in Victoria: Mine roosts in Eildon and Christmas Hills, Nargun maternity roost.

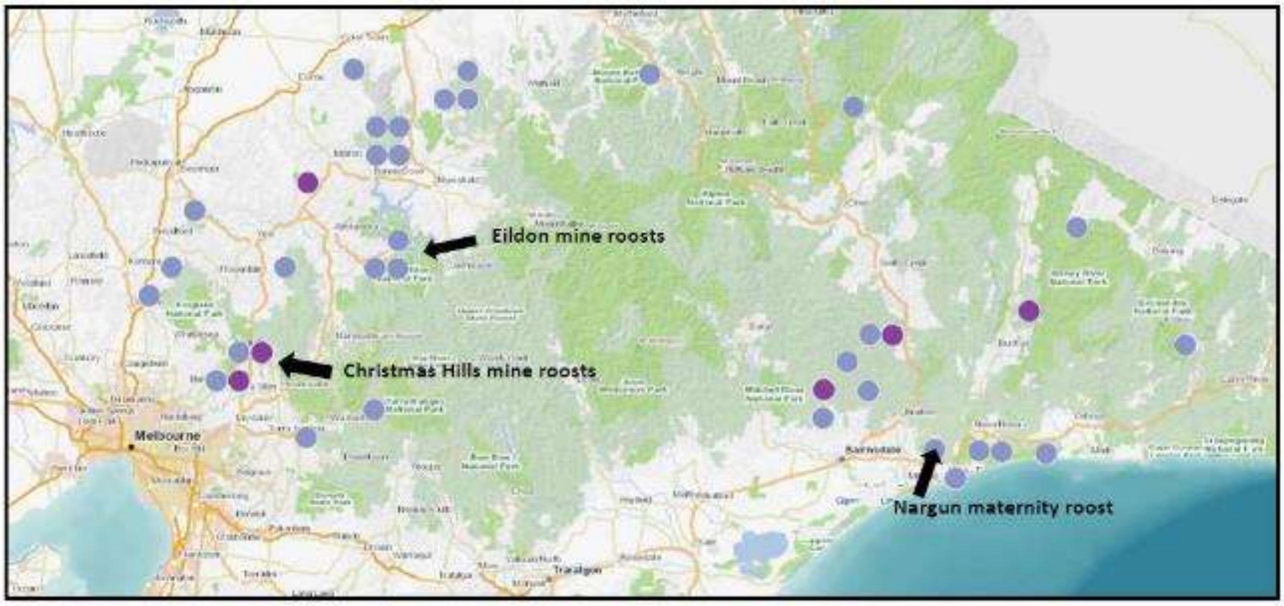

Figure 61. Locations for Eastern Horseshoe Bat

#	Actions:	
	No action	No specific management occurs anywhere within the proposed Victorian location for Bats.
1	Prevent human disturbance	Prevention of human disturbance at roost sites.
2	Biosecurity protocols	Develop and implement stringent biosecurity protocols to reduce the risk of introduction of White-nose Syndrome.
3	Gene mixing	No description given.
4	Protection from future fire	Identify this species and the Nargun Cave as a high priority asset in fire planning and management and undertake active targeted preventative actions.
5	Predator control	Targeted, localised control of introduced predators (cats and foxes).
6	Mine roost protection/ repair	Stabilise or repair key disused mine roosts to prevent collapsing.

Based on expert assessment the benefit of each action at each location for this species is as follows:

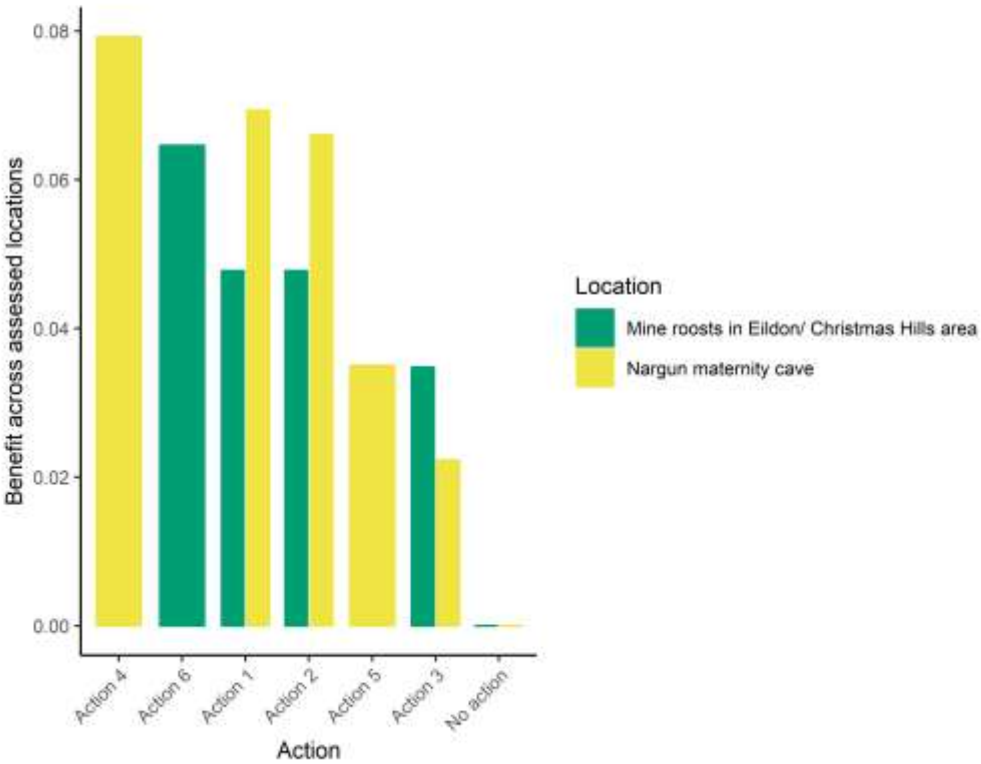

Figure 62. Benefit of each action/location combination to the Eastern Horseshoe Bat overall persistence probability across all assessed locations.

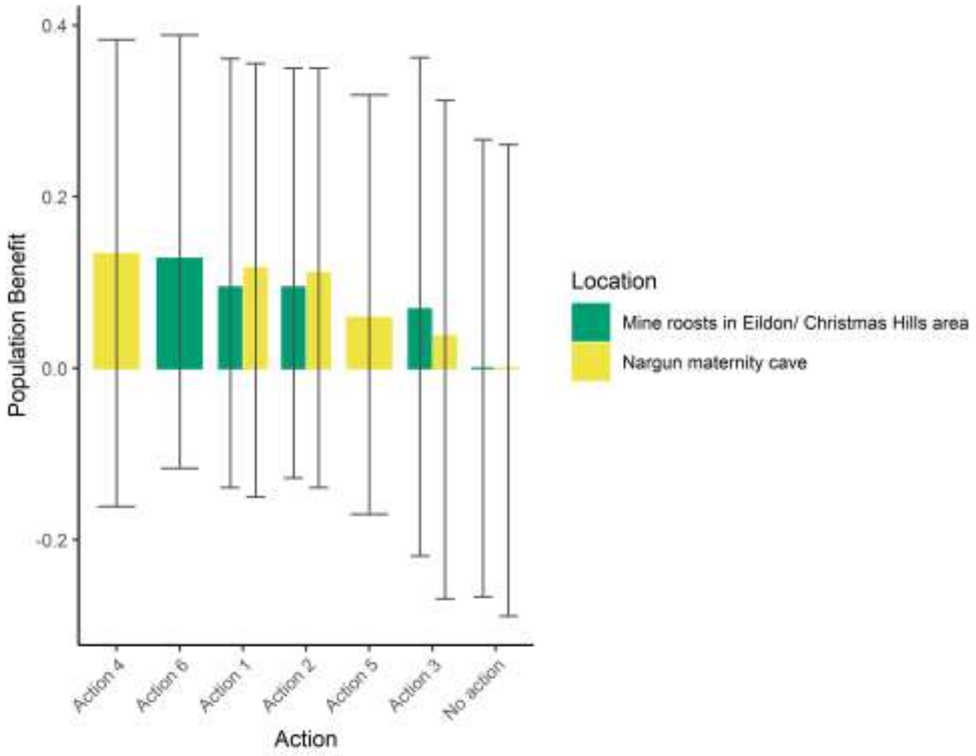

Figure 63. Mean change in Eastern Horseshoe Bat probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

There were single most beneficial actions for Eastern Horseshoe Bat at each site: protection of the Nargun Cave from fire and protection and repair of mine roosts. This suggests the greatest threat is loss of habitat due to direct disturbance. Isolation from humans and biosecurity protocols are additional actions deemed beneficial in each location.

Species: Southern-Eastern Long-Eared Bat (SELEB; *Nyctophilus corbeni*)

Number of experts: 10

Locations:

Nowingi

Current population in Victoria: There is only one known extant population of the SELEB in Victoria, the Nowingi area and adjacent section of the Hattah-Kulkyne National Park (abbreviated to Nowingi-Hattah). As such this was selected as the main site for assessment.

Despite extensive trapping surveys in this area, only low numbers of SELEB have been caught, and it is possible that there are only several hundred individuals in this population. These records are from a very small area of approximately 10 x 5 km. It is possible that this population is isolated from populations in NSW and South Australia as there is unsuitable habitat in between locations. As a result, the genetic variability of this population may be low.

The old growth mallee vegetation at the Nowingi-Hattah site is considered critical for the persistence of this species. This area has not been burnt for many years, and it may have some natural protection from bushfires originating from the west due to the salt pans of the Raak Plains. There remains however, a risk of bushfire, and to retain the old growth mallee, the site may need active protection from bushfire. Planned burning is also a threat to the old growth mallee at the site, as in mallee environments even planned burns can kill trees.

The SELEB primarily roosts in large hollows in old mallee trees. Other hollow-dependent species may be competing for these hollows, limiting the number available, and were fire to occur in this landscape it would dramatically reduce the number of hollows. Due to the long timeframes required for hollows of this size to form, the establishment of suitable artificial hollows may quickly provide additional alternative roosting sites.

The Nowingi-Hattah site is semi-arid with low rainfall and only intermittent standing water. An earthen tank is the only water source within the area, which often does not hold water year-round. Although it is not known how dependent the SELEB is on free water, the availability to such water could assist the species in the harsh climatic conditions.

As there is only one small known population currently in Victoria, an approach to increase the resilience of the species in Victoria would be to establish a new population by translocating animals to a suitable area some distance away from this site. As old growth mallee appears to be a critical habitat requirement, other areas of old growth mallee could provide potential translocation sites. An area in the west of the Sunset Country contains some patches of old growth mallee. A brief survey of this area failed to detect the species, but there appeared to be suitable habitat. Due to the small size of the Nowingi population any further reduction of numbers of individuals at this site could reduce the viability of this population. Therefore, animals may need to be sourced from NSW or South Australia.

Figure 64. The location of the Sunset Country in NW Victoria. The red circle indicates the Nowingi location and the blue circle the western Sunset Country location

Based on expert assessment the benefit of each action at each location for this species is as follows:

#	Actions:	
	No action	No specific management.
1	Protection from future fire	Identify and manage this species as a high priority asset in fire planning and management and undertake active preventative measures targeted at the species at this location, and ensure no planned burning occurs within this location.
2 3	Install artificial hollows at 10% or 50% of potential habitat	Artificial hollows at Nowingi and western section of Hattah Kulkyne National Park. The exact design and density of these is to be specified, but hollows will be installed based on the best available knowledge at the time. Prior to installation, factors to be considered include hollow design, density, position, maintenance, and monitoring.
4	Artificial water points	Ensure water is available all year round at Nowingi and western section of Hattah Kulkyne National Park.
5	Gene mixing	Gene mixing at Nowingi and western section of Hattah Kulkyne National Park using individuals from adjacent areas of NSW or South Australia.
6	Translocation	Establish a new population at Western Sunset Country. It is assumed that SELEB does not currently occur at this site. (One assessor suggested species may be present now, so rated the likelihood of the additional action on probability of persistence).

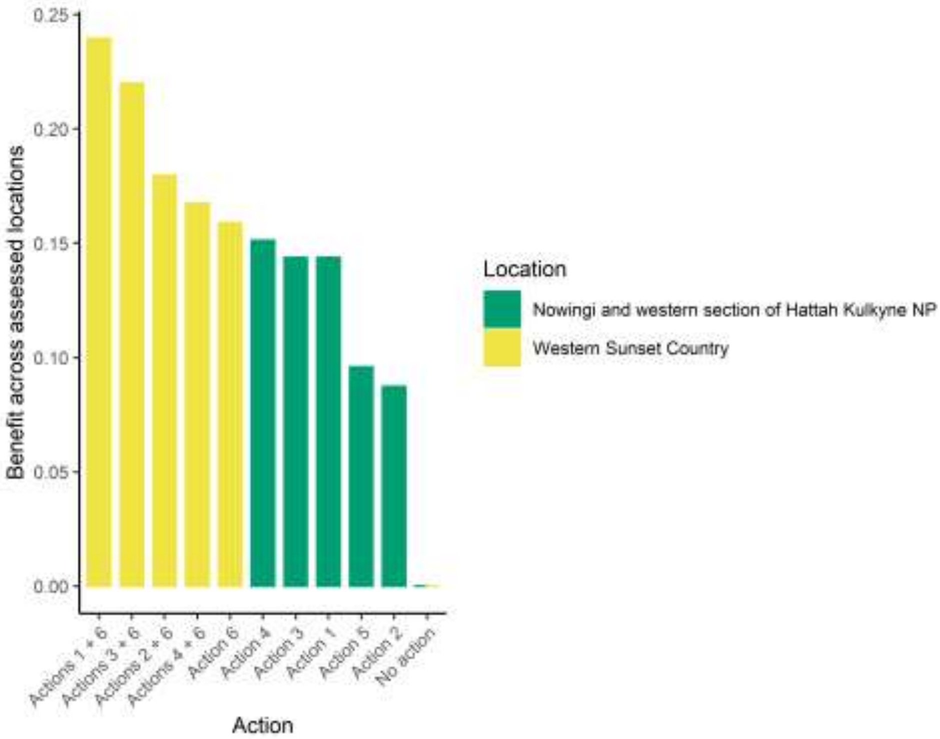

Figure 65. Benefit of each action/location combination to the Southern-Eastern Long-Eared Bat overall persistence probability across all assessed locations.

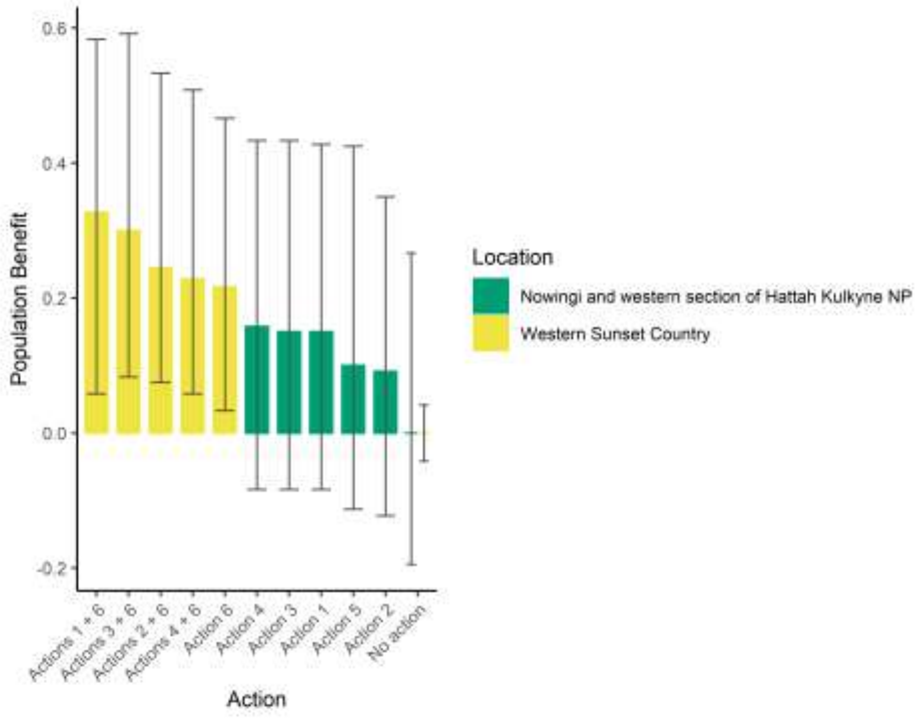

Figure 66. Mean change in Southern-Eastern Long-Eared Bat probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

The existing population of SELEB can experience the greatest benefit from ensuring water is consistently available, installing artificial habitat (50% suitable sites) or protection from fire. Gene mixing and installing a small number of hollows (10% suitable sites) is not expected to be as beneficial. Benefit to the Western Sunset country is entirely depending on whether translocation occurs to establish that population. If, so this will be best supported by protection from fire and the installation of large quantities (50% suitable sites) of artificial hollows.

Birds

Introduction

Five bird species were chosen for analysis based on unique threats and ecological factors, which allowed the taxon leads to explore intricate and practically useful action-location combinations. Species chosen are commonly recognised as at-risk, particularly after the 2019/20 bushfire season, but remedies are not covered by standard recovery techniques, thus requiring bespoke investigation.

Key knowledge gaps

I. Effect of projected climate change (rainfall deficits) on loss of food source

This model explores how reduced rainfall because of climate change could impact various types of vegetation. Vegetation cover and composition directly impacts birds as providers of food and shelter but are also major determinants to secondary biotic factors, such as predation and competition for resources.

Below are the best- and worst-case scenarios for this followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

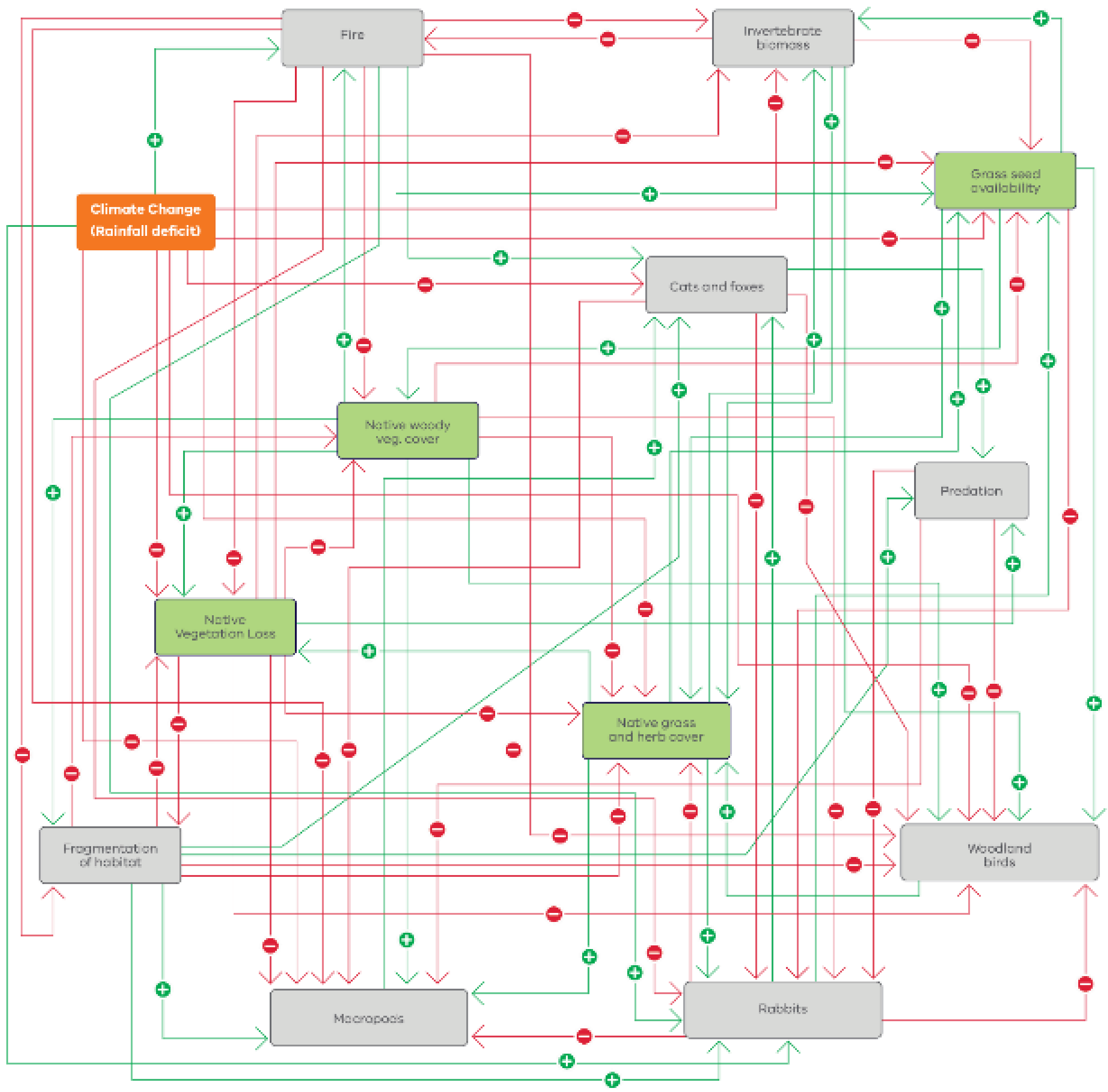

Figure 67. Best case scenario casual model for effect of projected climate change (rainfall deficits) on loss of food source. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

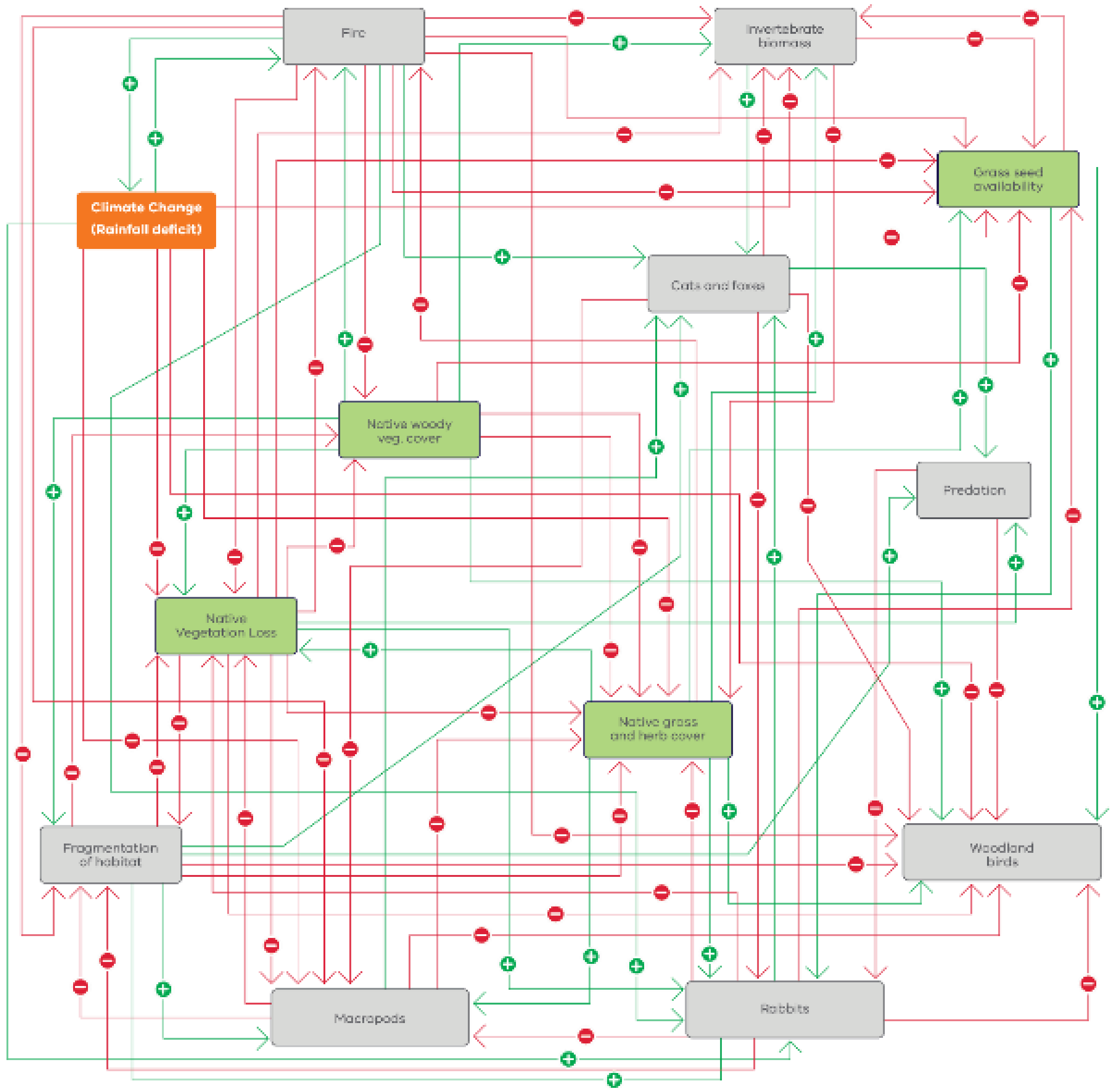

Figure 68. Worst case scenario casual model for effect of projected climate change (rainfall deficits) on loss of food source. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Fire	Rabbits	0.034
2	Grass seed availibility	Invertebrate biomass	0.026
2	Invertebrate biomass	Native grass and herb cover	0.026
2	Invertebrate biomass	Woodland birds	0.026
2	Fire	Grass seed availibility	0.026
2	Fire	Native grass and herb cover	0.026
2	Macropods	Native grass and herb cover	0.026
8	Climate Change Rainfall Deficit	Grass seed availibility	0.017
8	Climate Change Rainfall Deficit	Invertebrate biomass	0.017
8	Climate Change Rainfall Deficit	Native grass and herb cover	0.017
8	Climate Change Rainfall Deficit	Woodland birds	0.017
8	Cats and foxes	Rabbits	0.017
8	Grass seed availibility	Native grass and herb cover	0.017
8	Predation	Rabbits	0.017
8	Fire	Invertebrate biomass	0.017
8	Fire	Native woody veg cover	0.017
8	Fire	Fragmentation of habitat	0.017
8	Fire	Native Vegetation Loss	0.017
8	Fire	Woodland birds	0.017
8	Rabbits	Native grass and herb cover	0.017
8	Rabbits	Native Vegetation Loss	0.017
8	Macropods	Native Vegetation Loss	0.017
8	Macropods	Woodland birds	0.017

Rank	From	To	Proportional reduction
8	Native woody veg cover	Grass seed availbility	0.017
8	Native woody veg cover	Rabbits	0.017
8	Fragmentation of habitat	Native woody veg cover	0.017
8	Native Vegetation Loss	Grass seed availbility	0.017
8	Native Vegetation Loss	Invertebrate biomass	0.017
8	Native Vegetation Loss	Predation	0.017
8	Native Vegetation Loss	Native grass and herb cover	0.017
8	Native Vegetation Loss	Fragmentation of habitat	0.017
32	Climate Change Rainfall Deficit	Cats and foxes	0.009
32	Climate Change Rainfall Deficit	Fire	0.009
32	Climate Change Rainfall Deficit	Rabbits	0.009
32	Climate Change Rainfall Deficit	Macropods	0.009
32	Climate Change Rainfall Deficit	Native Vegetation Loss	0.009
32	Cats and foxes	Invertebrate biomass	0.009
32	Cats and foxes	Macropods	0.009
32	Cats and foxes	Woodland birds	0.009
32	Grass seed availbility	Woodland birds	0.009
32	Invertebrate biomass	Cats and foxes	0.009
32	Invertebrate biomass	Fire	0.009
32	Predation	Macropods	0.009
32	Predation	Woodland birds	0.009
32	Fire	Climate Change Rainfall Deficit	0.009
32	Fire	Cats and foxes	0.009
32	Fire	Macropods	0.009
32	Rabbits	Cats and foxes	0.009
32	Rabbits	Grass seed availbility	0.009
32	Rabbits	Macropods	0.009
32	Rabbits	Fragmentation of habitat	0.009
32	Rabbits	Woodland birds	0.009
32	Macropods	Fragmentation of habitat	0.009
32	Native grass and herb cover	Grass seed availbility	0.009
32	Native grass and herb cover	Invertebrate biomass	0.009
32	Native grass and herb cover	Rabbits	0.009
32	Native grass and herb cover	Native woody veg cover	0.009
32	Native grass and herb cover	Native Vegetation Loss	0.009
32	Native grass and herb cover	Woodland birds	0.009
32	Native woody veg cover	Invertebrate biomass	0.009
32	Native woody veg cover	Fire	0.009
32	Native woody veg cover	Macropods	0.009
32	Native woody veg cover	Native grass and herb cover	0.009
32	Native woody veg cover	Fragmentation of habitat	0.009
32	Native woody veg cover	Native Vegetation Loss	0.009
32	Native woody veg cover	Woodland birds	0.009
32	Fragmentation of habitat	Cats and foxes	0.009
32	Fragmentation of habitat	Predation	0.009
32	Fragmentation of habitat	Rabbits	0.009
32	Fragmentation of habitat	Macropods	0.009
32	Fragmentation of habitat	Native grass and herb cover	0.009
32	Fragmentation of habitat	Native Vegetation Loss	0.009
32	Fragmentation of habitat	Woodland birds	0.009
32	Native Vegetation Loss	Fire	0.009
32	Native Vegetation Loss	Rabbits	0.009
32	Native Vegetation Loss	Macropods	0.009
32	Native Vegetation Loss	Native woody veg cover	0.009

Figure 69. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for projected climate change (rainfall deficits) on loss of food source

The highest ranked links were fire on rabbits, grass seed availability on invertebrate biomass, invertebrate biomass on native grass and herb cover and woodland birds, fire on grass seed availability and native grass and herb cover, and macropods on native grass and herb cover. These links may be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.034 for the first action, and 0.026 for the other six.

II. Influence of wildfire and competition for prey resources by introduced predators on Victorian large forest owls

Owls primarily considered in this scenario are Powerful Owl (*Ninox strenua*), Sooty Owl (*Tyto tenebricosa*) and Masked Owl (*Tyto novaehollandiae*). A secondary but important relationship which is also tested in this model is the impact of competition for prey resources by introduced predators on large forest owls. This is something identified in the latest re-assessments of Victoria's threatened species list for Sooty Owl as being a potential key driver of decline.

Below are the best- and worst-case scenarios for this system (see section 1.3 for further detail in interpreting these models) followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

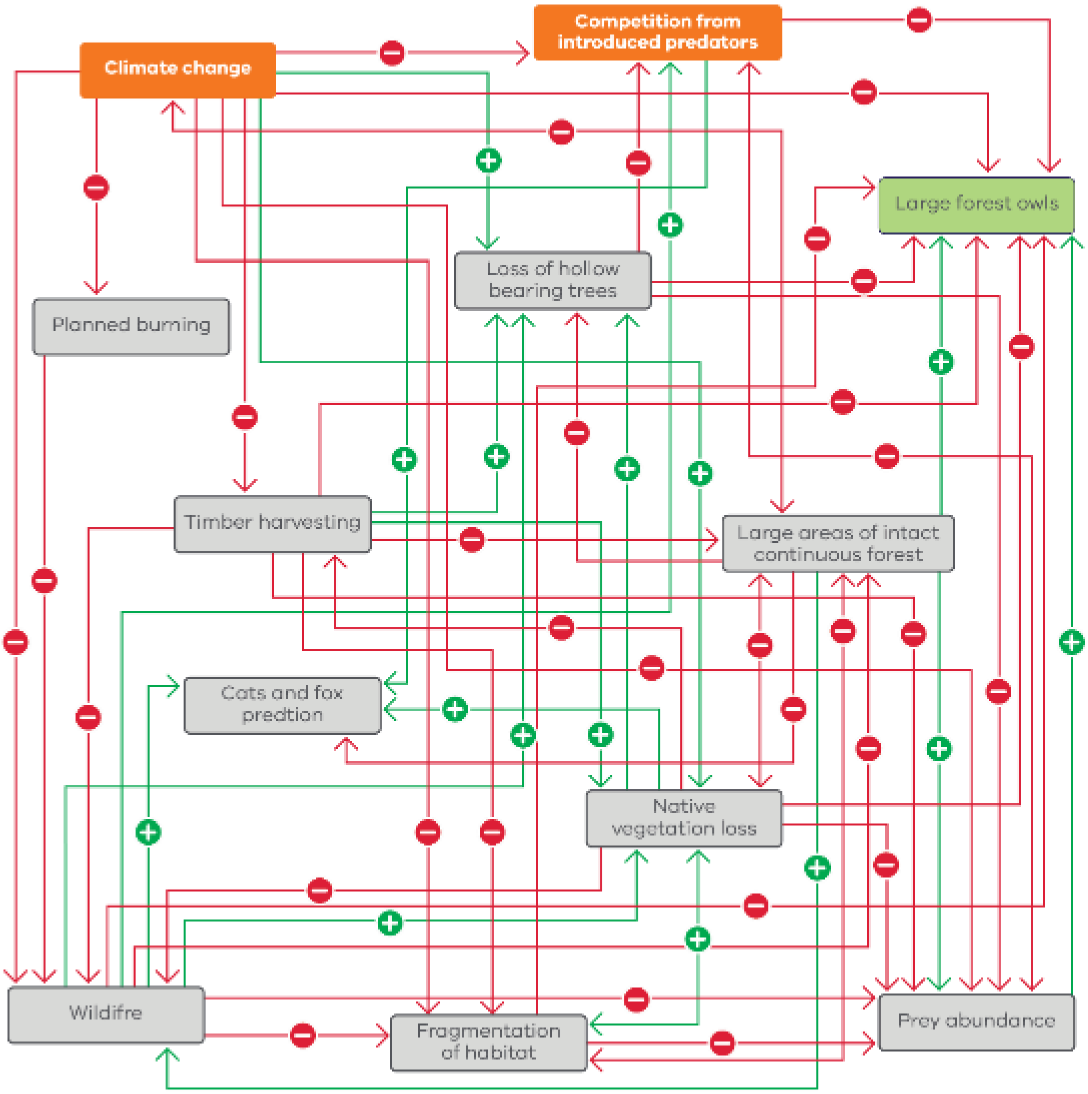

Figure 70. Best case scenario casual model for influence of wildfire and competition for prey resources by introduced predators on Victorian large forest owls.

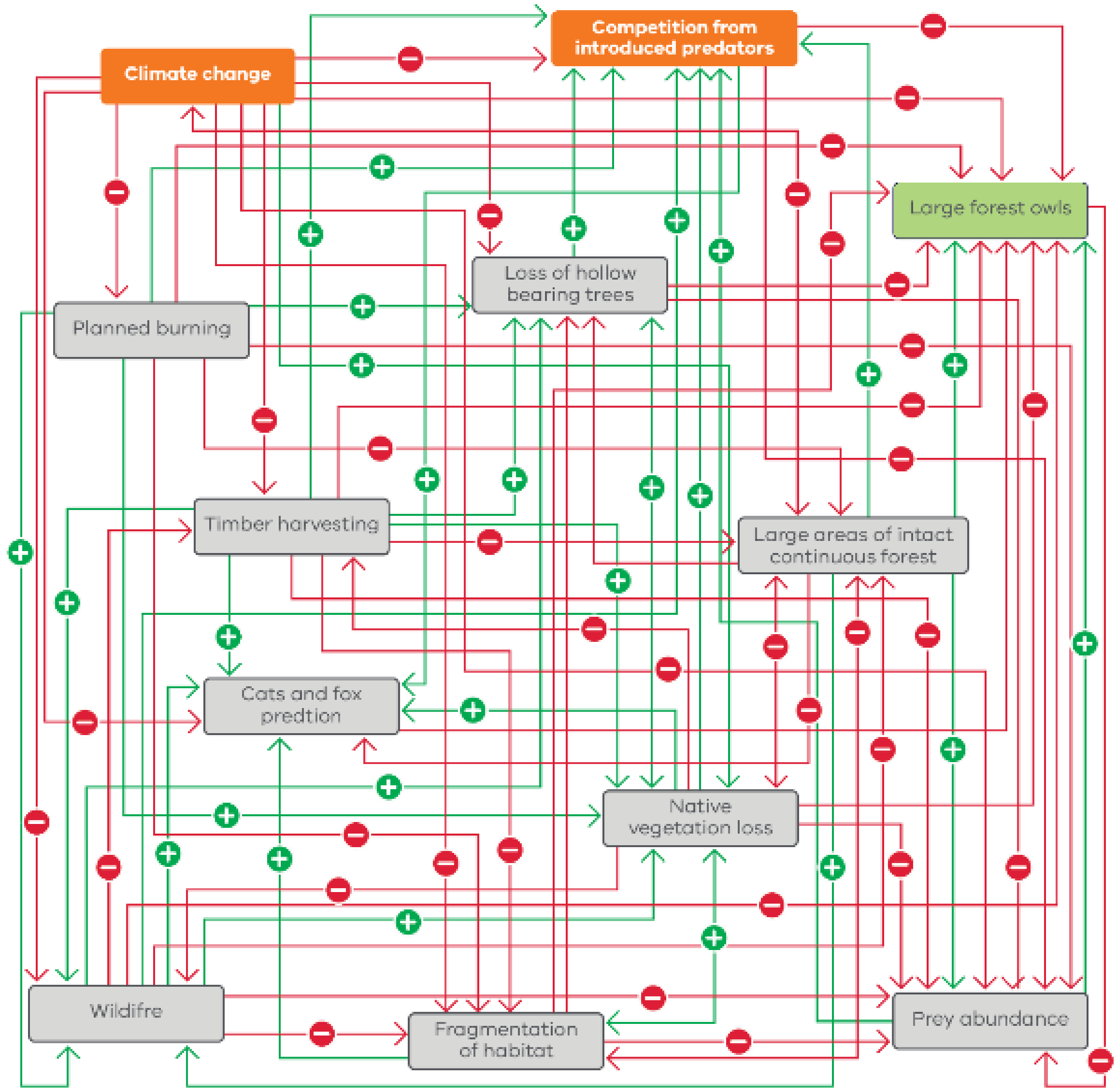

Figure 71. Worst case scenario casual model for influence of wildfire and competition for prey resources by introduced predators on Victorian large forest owls.

Rank	Knowledge gap	Proportional reduction
1	The influence of Climate Change on Loss of hollow bearing trees	0.041
1	The influence of Large areas of intact continuous forest on Competition from introduced predators	0.041
1	The influence of Planned burning on Wildfire	0.041
4	The influence of Prey abundance on Competition from introduced predators	0.031
4	The influence of Fragmentation of habitat on Competition from introduced predators	0.031
4	The influence of Planned burning on Prey abundance	0.031
4	The influence of Planned burning on Large areas of intact continuous forest	0.031
4	The influence of Planned burning on Fragmentation of habitat	0.031
9	The influence of Climate Change on Prey abundance	0.021
9	The influence of Climate Change on Large areas of intact continuous forest	0.021
9	The influence of Climate Change on Fragmentation of habitat	0.021
9	The influence of Climate Change on Native vegetation loss	0.021
9	The influence of Climate Change on Competition from introduced predators	0.021
9	The influence of Climate Change on Large forest owls	0.021
9	The influence of Wildfire on Prey abundance	0.021
9	The influence of Wildfire on Competition from introduced predators	0.021
9	The influence of Wildfire on Loss of hollow bearing trees	0.021
9	The influence of Fragmentation of habitat on Prey abundance	0.021
9	The influence of Native vegetation loss on Competition from introduced predators	0.021
9	The influence of Competition from introduced predators on Prey abundance	0.021
9	The influence of Competition from introduced predators on Large forest owls	0.021
9	The influence of Timber harvesting on Prey abundance	0.021
9	The influence of Timber harvesting on Competition from introduced predators	0.021
9	The influence of Timber harvesting on Loss of hollow bearing trees	0.021
9	The influence of Timber harvesting on Large forest owls	0.021
9	The influence of Planned burning on Native vegetation loss	0.021
9	The influence of Planned burning on Competition from introduced predators	0.021
9	The influence of Planned burning on Loss of hollow bearing trees	0.021
9	The influence of Planned burning on Large forest owls	0.021
9	The influence of Loss of hollow bearing trees on Prey abundance	0.021
31	The influence of Climate Change on Cat and fox predation	0.010
31	The influence of Climate Change on Wildfire	0.010
31	The influence of Climate Change on Timber harvesting	0.010
31	The influence of Cat and fox predation on Large forest owls	0.010
31	The influence of Wildfire on Cat and fox predation	0.010
31	The influence of Wildfire on Large areas of intact continuous forest	0.010
31	The influence of Wildfire on Fragmentation of habitat	0.010
31	The influence of Wildfire on Native vegetation loss	0.010
31	The influence of Wildfire on Timber harvesting	0.010
31	The influence of Wildfire on Large forest owls	0.010
31	The influence of Large areas of intact continuous forest on Climate Change	0.010
31	The influence of Large areas of intact continuous forest on Cat and fox predation	0.010
31	The influence of Large areas of intact continuous forest on Wildfire	0.010
31	The influence of Fragmentation of habitat on Cat and fox predation	0.010
31	The influence of Fragmentation of habitat on Loss of hollow bearing trees	0.010
31	The influence of Fragmentation of habitat on Large forest owls	0.010
31	The influence of Native vegetation loss on Cat and fox predation	0.010
31	The influence of Native vegetation loss on Prey abundance	0.010
31	The influence of Native vegetation loss on Wildfire	0.010
31	The influence of Native vegetation loss on Loss of hollow bearing trees	0.010
31	The influence of Timber harvesting on Cat and fox predation	0.010
31	The influence of Timber harvesting on Wildfire	0.010
31	The influence of Loss of hollow bearing trees on Native vegetation loss	0.010
31	The influence of Loss of hollow bearing trees on Competition from introduced predators	0.010
31	The influence of Loss of hollow bearing trees on Large forest owls	0.010
31	The influence of Large forest owls on Prey abundance	0.010

Figure 72. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for influence of wildfire and competition for prey resources by introduced predators on Victorian large forest owls

The highest ranked links were climate change on loss of hollow bearing trees, large areas of intact contiguous forest on competition from introduced predators and planned burning on wildfire. These may be good candidates for research projects, as they each represent the equal highest reduction in uncertainty of 0.041.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 73 and 74) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Glossy Black-Cockatoo (*Calyptorhynchus lathami)*

Number of experts: 8

Locations:

East Gippsland

Current population in Victoria: Over 95% of records are from the East Gippsland Forest Management Area, mostly in the areas east of the Wingan River and surrounding Mallacoota and Genoa. Scattered records occur mostly south of the Princes Highway between Cann River and Lake Tyers. Vagrant to other parts of the state such as North-east Victoria, South Gippsland and Western Port Phillip Bay.

Black She oak *(Allocasuarina littoralis)* is a key food plant for this species and a limiting factor in any potential habitat.

#	Actions:	
	No Action	No management of wild populations. No action estimates for sites where no population present have been assumed to be zero.
1	Supplementary planting	Planting approximately 200 hectares of Black She oak *(Allocasuarina littoralis)* in suitable locations near existing habitat around Genoa.
2	Translocation	Over two years translocate 30-40 birds from wild populations in Vic\NSW to existing unoccupied suitable habitat at Wilson's Promontory.
		Over two years translocate 30-40 birds from wild populations in Vic\NSW to existing unoccupied suitable habitat around identified Port Phillip\Western Port Bay Woodland.
3	Harvesting from source populations	Over two years translocate 30-40 birds from wild populations in Vic\NSW to nominated ex situ translocation sites.
4	Supplementary artificial nesting hollows	Targeted supplementation of artificial nesting hollows within and around existing habitat at Genoa to reinstate naturally occurring hollow densities.

Based on expert assessment the benefit of each action at each location for this species is as follows:

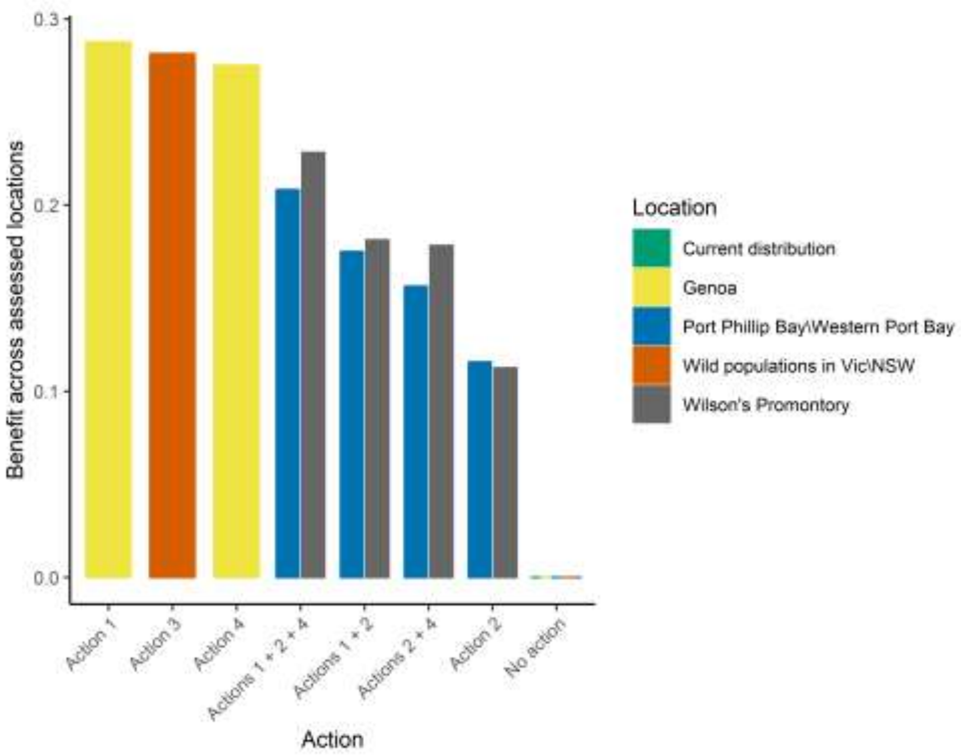

Figure 73. Benefit of each action/location combination to the Glossy Black-Cockatoo overall persistence probability across all assessed locations.

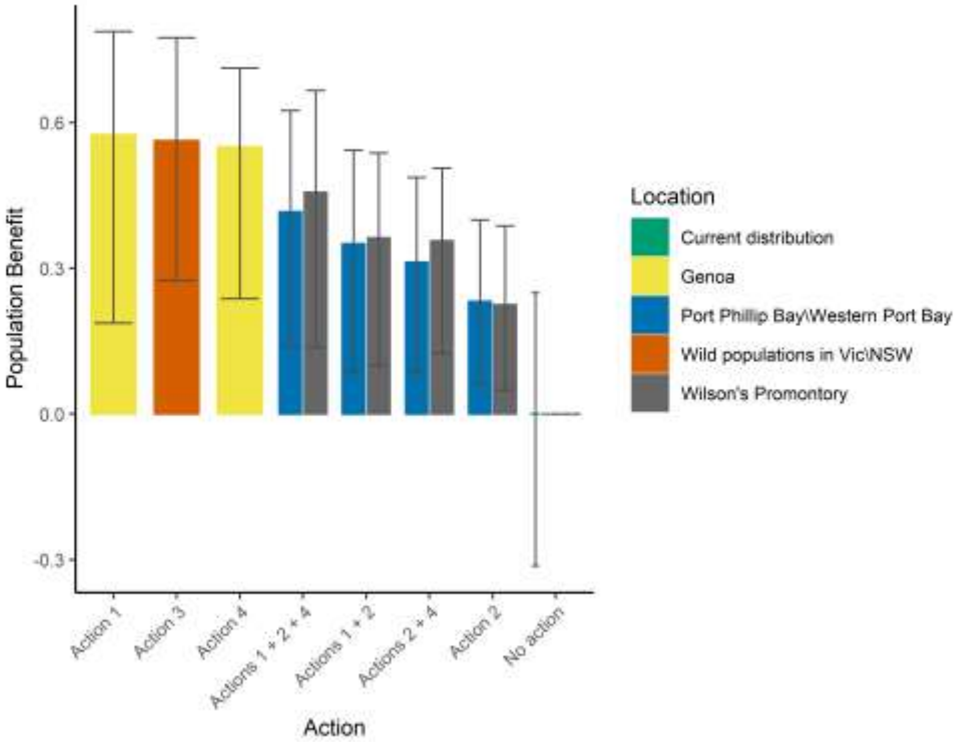

Figure 74. Mean change in Glossy Black-Cockatoo probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Actions for this species depend on location within the current distribution. Supplementary planting of Black She oak around Genoa is ranked most beneficial. The remaining actions suggest a translocation strategy from wild populations to Wilson's Promontory or existing unoccupied suitable habitat around identified Port Phillip\Western Port Bay Woodland. Harvesting of birds from the source population (action 3) is seen as likely to be successful, and the likelihood of benefit to the new population (actions 2) increases with additional provisions of food (action 1) and habitat (action 4). Artificial hollows would also be highly beneficial to existing populations at Genoa.

Species: Eastern Ground Parrot (*Pezoporus wallicus)*

Number of experts: 9

Locations:

Coastal heathland

Current populations in Victoria: Recent strongholds –coastal heathland from about Marlo and Cape Conran to the NSW border. Landscape scale wildfire impacts from 2019\20 in East Gippsland have significantly depleted habitat along this coastal belt, recovery and status of impacts is still being assessed.

Fragmentation of habitat, fire and predation by cats and foxes are key threats. Genetic diversity is likely poor in isolated sub-populations. Age class\structure of heathland habitat is critical for species persistence. Outlying relic populations at Wilson's Promontory in south Gippsland and Discovery Bay Coastal Park in far south-west Victoria may present as potential areas for translocation. Other options include assisted recolonisation to previous habitat within the East Gippsland wildfire footprint once appropriate habitat has regenerated.

#	Actions:	
	No Action	No management of wild populations.
1	Fire Management (Howe Flat)	Long term implementation of fire regimes targeted to promote retention and regeneration of Eastern Ground Parrot habitat. This would include exclusion of fire to achieve optimum age-class vegetation structure in conjunction with management to maintain a mosaic of fire age classes across suitable habitat (identified through remote sensing, ground-truthing and field surveys).
2	Translocation (Wilson's Promontory)	Over two years translocate 30 birds from wild populations in Vic\NSW to existing suitable habitat at Wilson's Promontory
2	Translocation (SW Victoria - Discovery Bay Coastal Park)	Over two years translocate 30 birds from wild populations in Vic\NSW to existing suitable habitat within Discovery Bay Coastal Park in far south-west Victoria
3	Harvesting from source populations	Over two years translocate 30 birds from wild populations in Vic\NSW to nominated ex situ translocation sites.
2	Translocation into regenerating habitat within wildfire footprint in East Gippsland	Over two years reintroduce 30 birds from wild populations in Vic\NSW to suitable habitat at Mallacoota\Shipwreck Creek (identified through remote sensing, ground-truthing and field surveys).
2	Translocation into regenerating habitat within wildfire footprint in East Gippsland	Over two years reintroduce 30 birds from wild populations in Vic\NSW to suitable habitat around Cape Conran (identified through remote sensing, ground-truthing and field surveys).
4	Predator Control	A combination of fox and cat baiting programs across significant Victorian populations – Cape Conran, Marlo, Mallacoota, Howe Wilderness

Based on expert assessment the benefit of each action at each location for this species is as follows:

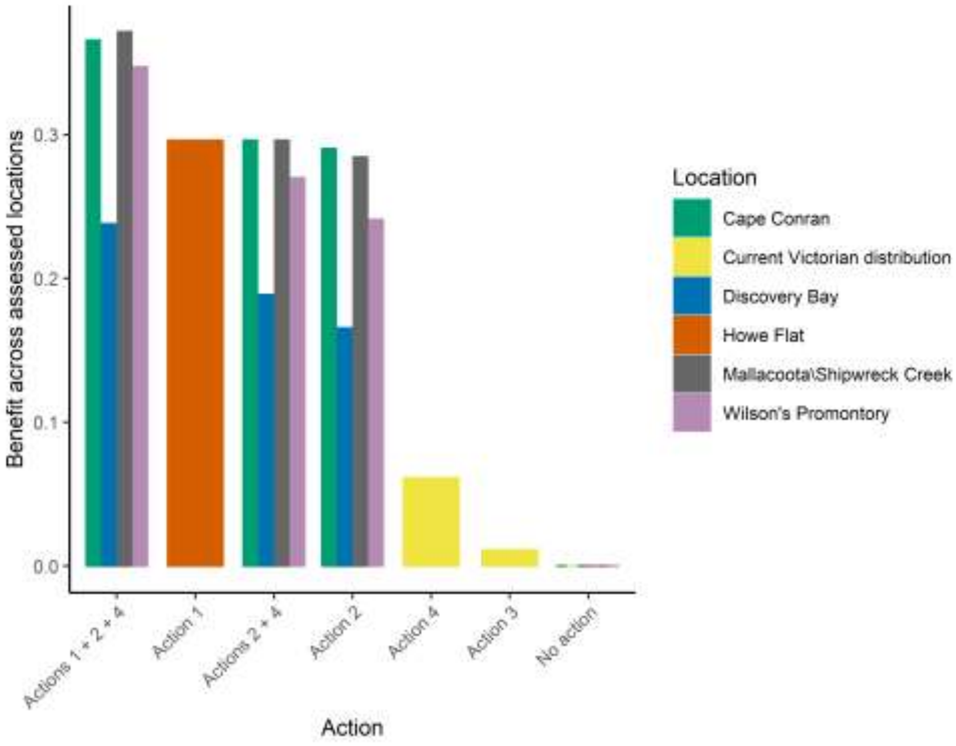

Figure 75. Benefit of each action/location combination to the Eastern Ground Parrot overall persistence probability across all assessed locations.

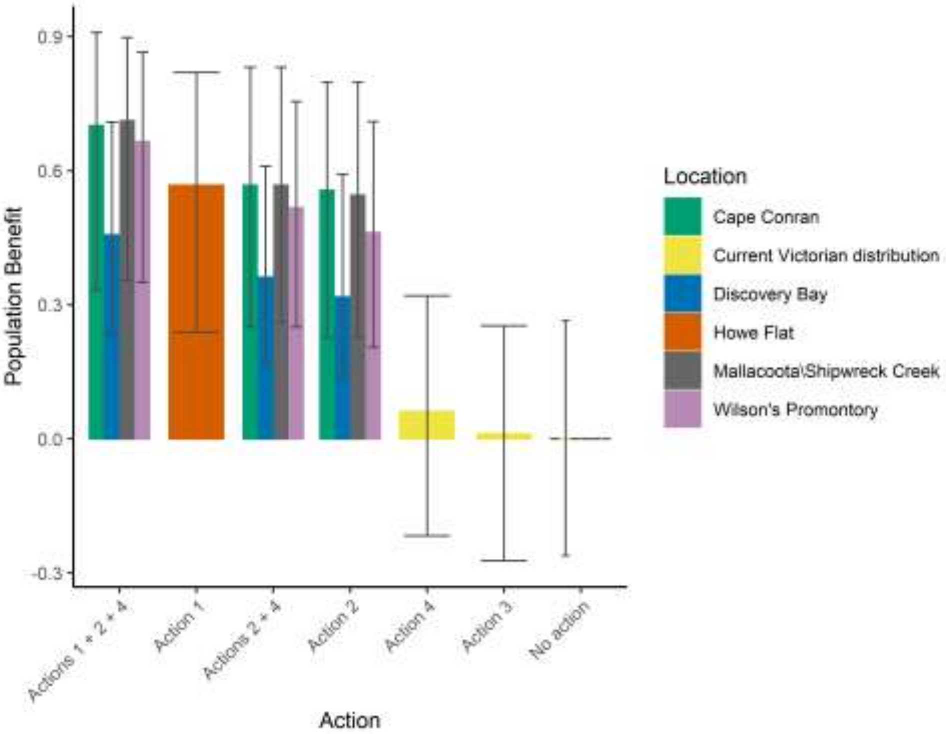

Figure 76. Mean change in Eastern Ground Parrot probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Elicited experts have determined that the most appropriate management response to improve probability of persistence for the Eastern Ground Parrot is translocation- either into new areas or reintroduction into regenerating fire-effected East Gippsland. Discovery Bay is the least preferred location for translocation, and regenerated habitat was ranked higher than new locations under each combination of complementary management. Management within current populations reflect major threats as- fire at Howe Flat and feral predators across the state.

Species: Mallee Emu-Wren (*Stipiturus mallee*)

Number of experts: 9

Locations: Current Victorian distribution, Annuello\South-west Big Desert

Current Population in Victoria: Confined to a limited number of Mallee reserves in far north-west Victoria - Murray-Sunset National Park, Big Desert Wilderness, Wyperfeld National Park and Hattah Kulkyne National Park. Vulnerable to a single stochastic event such as a wildfire. Translocation of this species to non-contiguous unoccupied suitable habitat may be a way of mitigating the threat of losing entire populations to a single wildfire event or a series of repeated wildfire events. Habitat condition (age class, structure) critical for species persistence and this will need to be identified in any potential ex situ locations. Other actions in conjunction with translocation might include a combination of remote sensing and ground-truthing to determine important habitat and refugia, predator control, establishment of appropriate fire regimes and genetic mixing between sub-populations.

The far south-west corner of Big Desert has been identified as a potential area for re-introduction as it comprises a large area of unoccupied habitat, suitable post-fire age-class vegetation and connectivity to habitat on the South Australian side of the border.

#	Actions:	
	No Action	No management of wild populations.
1	Harvesting for translocation	Translocation of (~80) birds from source populations to identified disjunct suitable habitat (>5000ha) over (2 years).
2	Translocation to disjunct non-occupied suitable habitat within reserve system	Translocation of (~80) birds from source populations to identified disjunct suitable habitat (>5000ha) over (2 years) (e.g. Annuello Flora & Fauna Reserve, South-west Big Desert (unoccupied habitat).
3	Gene Mixing between current sub-populations	Translocation of (~80) birds over (2 years) across sub-populations to increase genetic diversity (e.g. Murray Sunset National Park to Wyperfeld\Big Desert).
4	Predator control	A combination of fox and cat baiting programs across current distribution **-**Big Desert, Wyperfeld NP, Murray-Sunset NP, Hattah Kulkyne NP
5	Fire Management	Long term implementation of fire regimes targeted to promote retention and regeneration of Mallee Emu-wren habitat. May include exclusion of planned burning, strategic burning to augment habitat and establishment of fuel breaks to prevent wildfire spread (identified through remote sensing, ground-truthing and field surveys).

Based on expert assessment the benefit of each action at each location for this species is as follows:

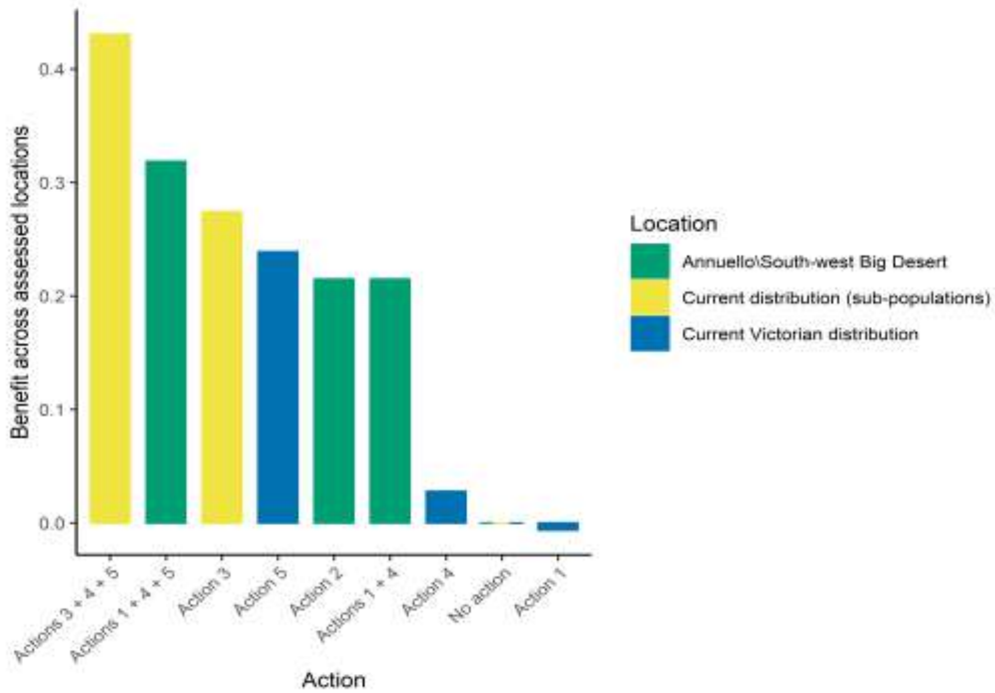

Figure 77. Benefit of each action/location combination to the Mallee Emu-Wren overall persistence probability across all assessed locations.

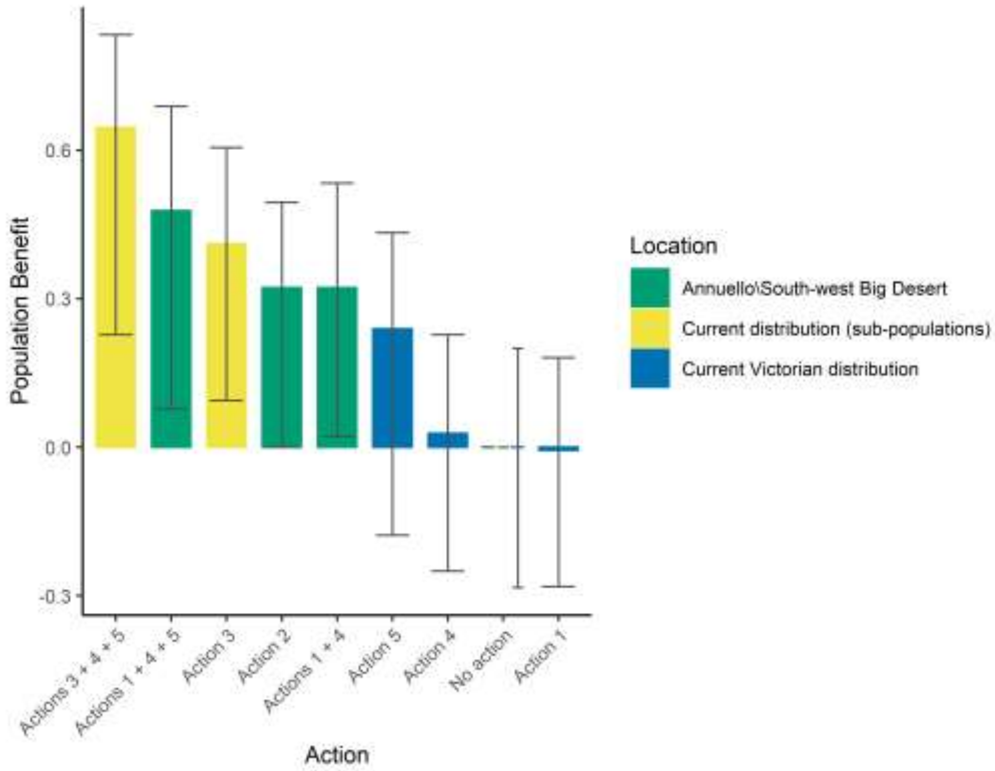

Figure 78. Mean change in Mallee Emu-Wren probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Gene mixing between current sub-populations was rated as highly beneficial for boosting resilience to future threats and may be combined with the existing (targeted) management of fire and predators. Fire and predators represent major threats, which have exacerbated risk to the Mallee Emu-Wren as a result of its restricted distribution. Translocation was ranked moderately compared to other actions in this elicitation.

Species: Red-Lored Whistler (*Pachycephala rufogularis*)

Number of experts: 8

Locations: Current Victorian distribution, Annuello\Hattah Kulkyne

Current population in Victoria: Confined to a limited number of Mallee reserves in far north-west Victoria - Murray-Sunset National Park, Big Desert Wilderness and Wyperfeld National Park. Vulnerable to a single stochastic event such as a wildfire. Translocation of this species to noncontiguous unoccupied suitable habitat may be a way of mitigating the threat of losing entire populations to a single wildfire event or a series of repeated wildfire events. Habitat condition (age class, structure) critical for species persistence and this will need to be identified in any potential ex situ locations. Other actions in conjunction with translocation might include a combination of remote sensing and ground-truthing to determine important habitat and refuges as well as predator control and establishment of appropriate fire regimes.

#	Actions:	
	No Action	No management of wild populations.
1	Harvesting for translocation	Translocation of (~20) birds from source populations to identified disjunct reserve with suitable habitat (>5000ha) over (1 year).
2	Translocation to disjunct non-occupied suitable habitat within reserve system	Translocation of (~20) birds from source populations to identified disjunct reserve with suitable habitat (>5000ha) over (1 year) (eg. Annuello Flora & Fauna Reserve, Hattah-Kulkyne National Park).
3	Predator control	A combination of fox and cat baiting programs across current distribution- Big Desert, Wyperfeld NP, Murray-Sunset NP.
4	Fire Management	Long term implementation of fire regimes across current distribution- Big Desert, Wyperfeld NP, Murray-Sunset NP. Targeted to promote retention and regeneration of optimum of Red-lored Whistler habitat (post-fire age class 20 - 40 years). May include exclusion of planned burning, strategic burning to augment habitat and establishment of fuel breaks to prevent wildfire spread (identified through remote sensing, ground-truthing and field surveys).

Based on expert assessment the benefit of each action at each location for this species is as follows:

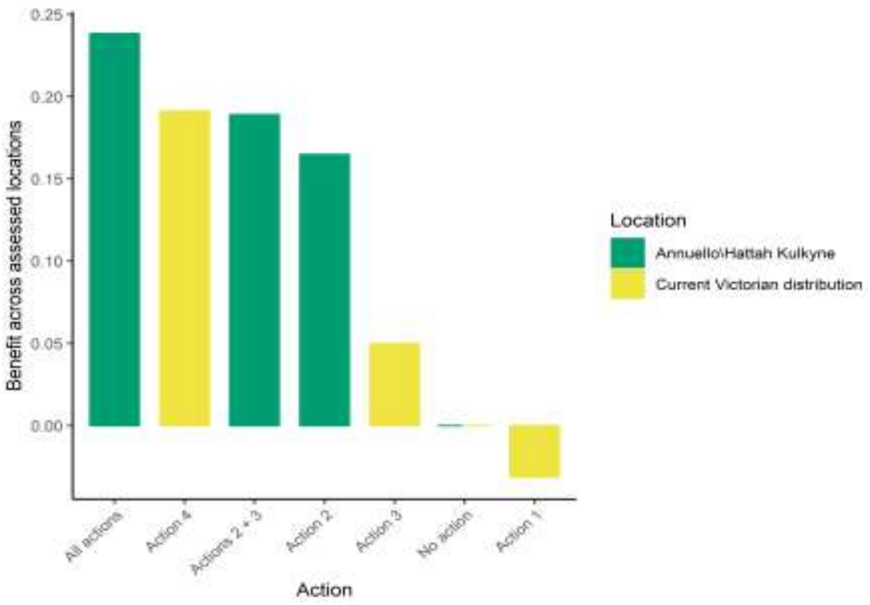

Figure 79. Benefit of each action/location combination to the Red-Lored Whistler overall persistence probability across all assessed locations.

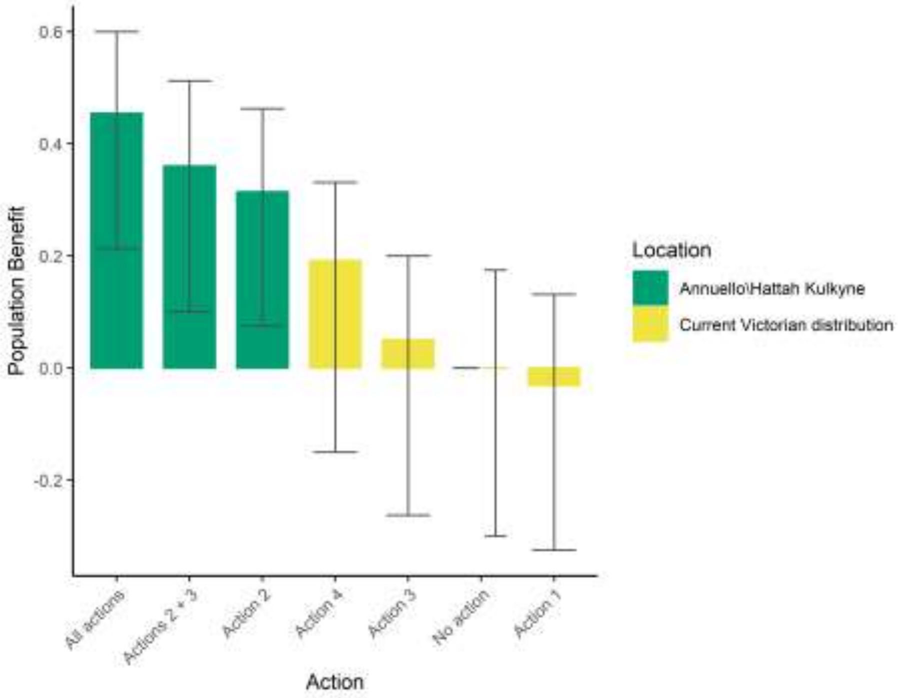

Figure 80. Mean change in Red-Lored Whistler probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

These results suggest the possible benefit of translocation of the Red-Lored Whistler to the new site at Annuello\Hattah Kulkyne, but this would come at a cost (disbenefit) to the source population. The current population would benefit most from improved and strategic fire management (see details action 4 above), reflecting its major threat.

Species: Striated Grasswren (*Amytornis striatus*)

Number of experts: 9

Locations: Current Victorian distribution, South-west Big Desert

Current population in Victoria: Confined to a limited number of Mallee reserves in far north-west Victoria - Murray-Sunset National Park, Big Desert Wilderness, Wyperfeld National Park, Hattah Kulkyne National Park & Annuello Flora & Fauna Reserve. Vulnerable to a single stochastic event such as a wildfire. Translocation of this species to noncontiguous unoccupied suitable habitat may be a way of mitigating the threat of losing entire populations to a single wildfire event or a series of repeated wildfire events. Habitat condition (age class, structure) critical for species persistence and this will need to be identified in any potential ex situ locations. Other actions in conjunction with translocation might include a combination of remote sensing and ground-truthing to determine important habitat and refugia, predator control, establishment of appropriate fire regimes and genetic mixing between sub-populations.

The far south-west corner of Big Desert has been identified as a potential area for re-introduction as it comprises a large area of unoccupied habitat, suitable post-fire age-class vegetation and connectivity to habitat on the South Australian side of the border.

#	Actions:	
	No Action	No management of wild populations.
1	Harvesting for translocation	Translocation of (~100) birds from source populations to identified disjunct suitable habitat (>5000ha) over (3 years).
2	Translocation to disjunct non-occupied suitable habitat within reserve system	Translocation of (~100) birds from source populations to identified disjunct suitable habitat (>5000ha) over (3 years) (eg. South-west Big Desert (unoccupied habitat).
3	Genetic mixing between current sub-populations	Translocation of (~100) birds over (3 years) across sub-populations to increase genetic diversity (eg. From Hattah Kulkyne NP to Wyperfeld NP).
4	Predator control	A combination of fox and cat baiting programs across current distribution **-**Big Desert, Wyperfeld NP, Murray-Sunset NP, Hattah Kulkyne NP, Annuello FFR.
5	Fire Management	Long term implementation of fire regimes targeted to promote retention and regeneration of Striated Grasswren habitat. May include exclusion of planned burning, strategic burning to augment habitat and establishment of fuel breaks to prevent wildfire spread (identified through remote sensing, ground-truthing and field surveys).

Based on expert assessment the benefit of each action at each location for this species is as follows:

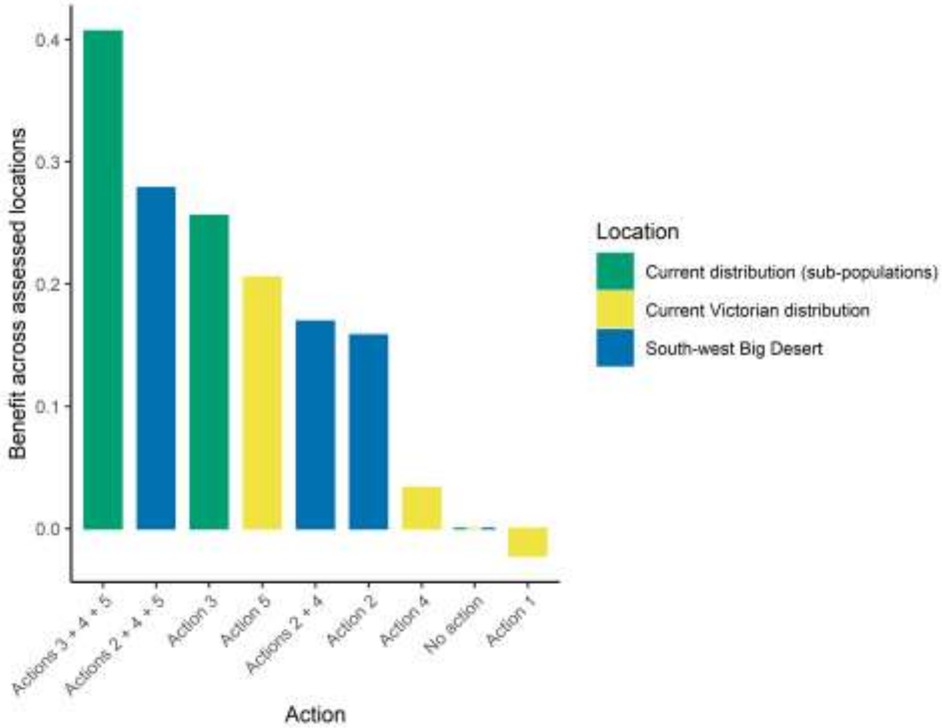

Figure 81. Benefit of each action/location combination to the Striated Grasswren overall persistence probability across all assessed locations.

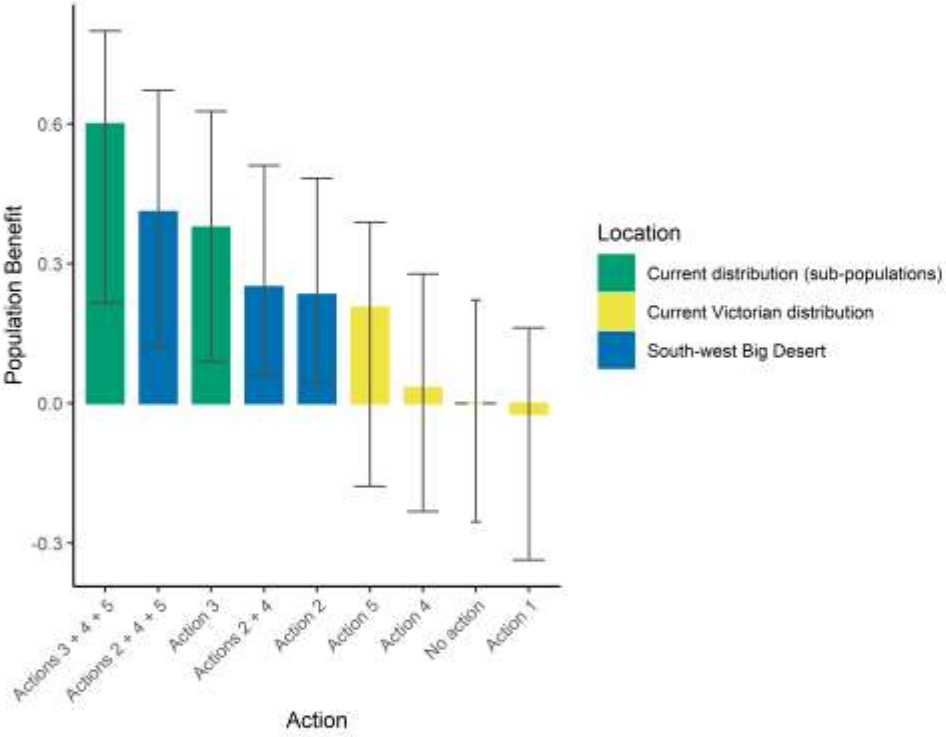

Figure 82. Mean change in Striated Grasswren probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate)

Results show that a combination of actions incorporating fire and predator control would greatly benefit both the existing collection of Striated Grasswren sub-populations, as well as a potential new population in South-west Big Desert. Translocation is rated as moderately beneficial, however greater gains are observed by improving the resilience of existing subpopulations through genetic mixing.

Bryophytes and algae

Introduction

This group sought to represent bryophyte and freshwater algae which are priorities for conservation. There is a limited pool of expertise from which to elicit information about threats and appropriate management actions, compared with most other taxonomic groups. In addition, experts generally have specific knowledge of threatened species that are represented by very few observations within Victoria. However, experts were found and approached to contribute based on experience with the relevant taxa as well as expertise in biodiversity management and related advisory roles or research. The result was an assessment of eight bryophyte species (grouped into five sets of actions and locations), two algae species, and an algal community. Species were designed to be representative, with benefits of actions to extend more broadly to the community.

The specific needs of freshwater algae have been formulated to improve their resilience to large scale disturbance. It considers all scales of habitat requirements including:

- Lichenised fungi (algal symbiont), and in association with other plants (e.g. Proteaceae)
- Freshwater algae in shallow wetlands
- Freshwater algae in bogs and mires
- Freshwater algae in deep lakes and reservoirs
- Freshwater algae in running waters
- Terrestrial algae on snow, soil surface, rocks, and plants (particularly rainforest and riparian plants)
- Brackish and marine algae in estuaries, salt marshes, interdunal swales, open coastal marine systems

See supplementary report for external reference material and further information.

Key knowledge gaps

I. Loss of rainforest microhabitats for bryophytes caused by encroachment of eucalypts

This model describes the effects of eucalypt encroachment on temperate rainforests, and the impact on bryophyte richness and cover. The model considers temperature and rainfall as major, long-term drivers of forest composition, notably the composition and cover of canopy species. As the closed structure of rainforest canopy makes way for eucalypt-dominated forest, the loss of rainforest sub-canopy climatic conditions and associated microhabitats is predicted to result in a decline in bryophyte richness and cover.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

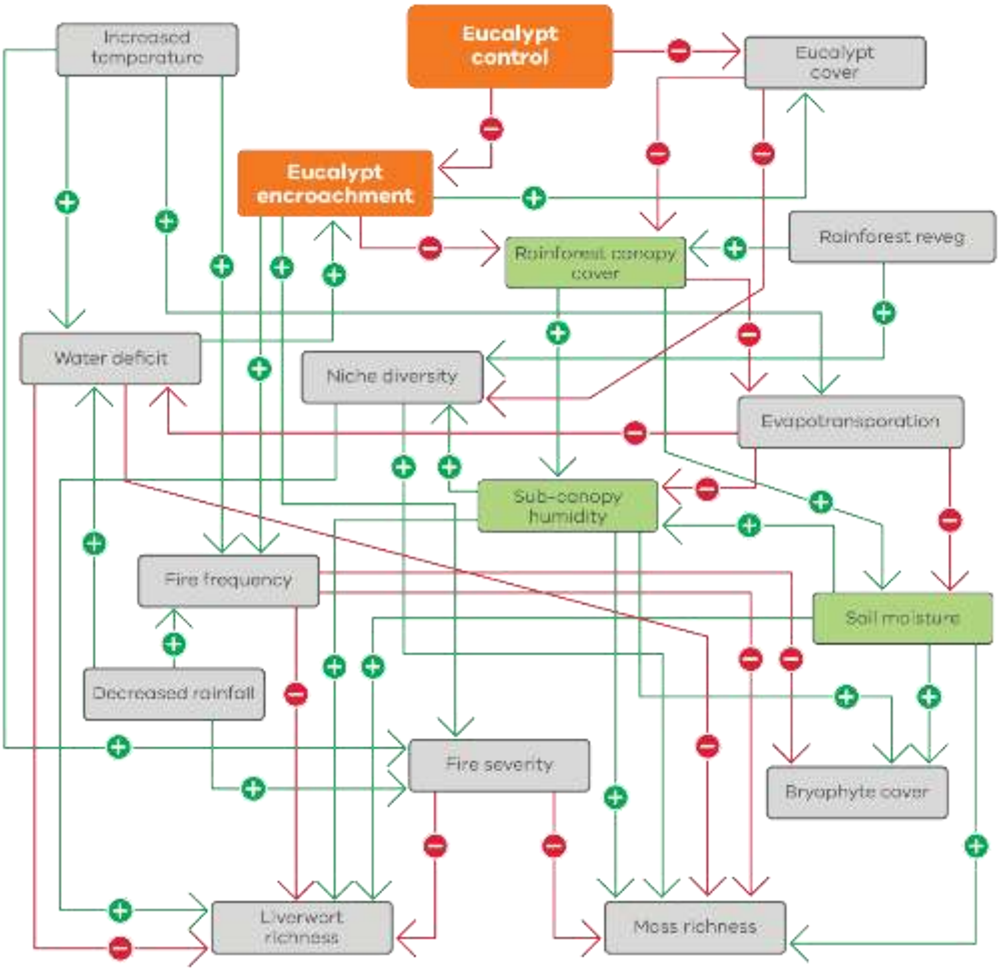

Figure 83. Best case scenario casual model for loss of rainforest microhabitats for bryophytes caused by encroachment of eucalypts. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

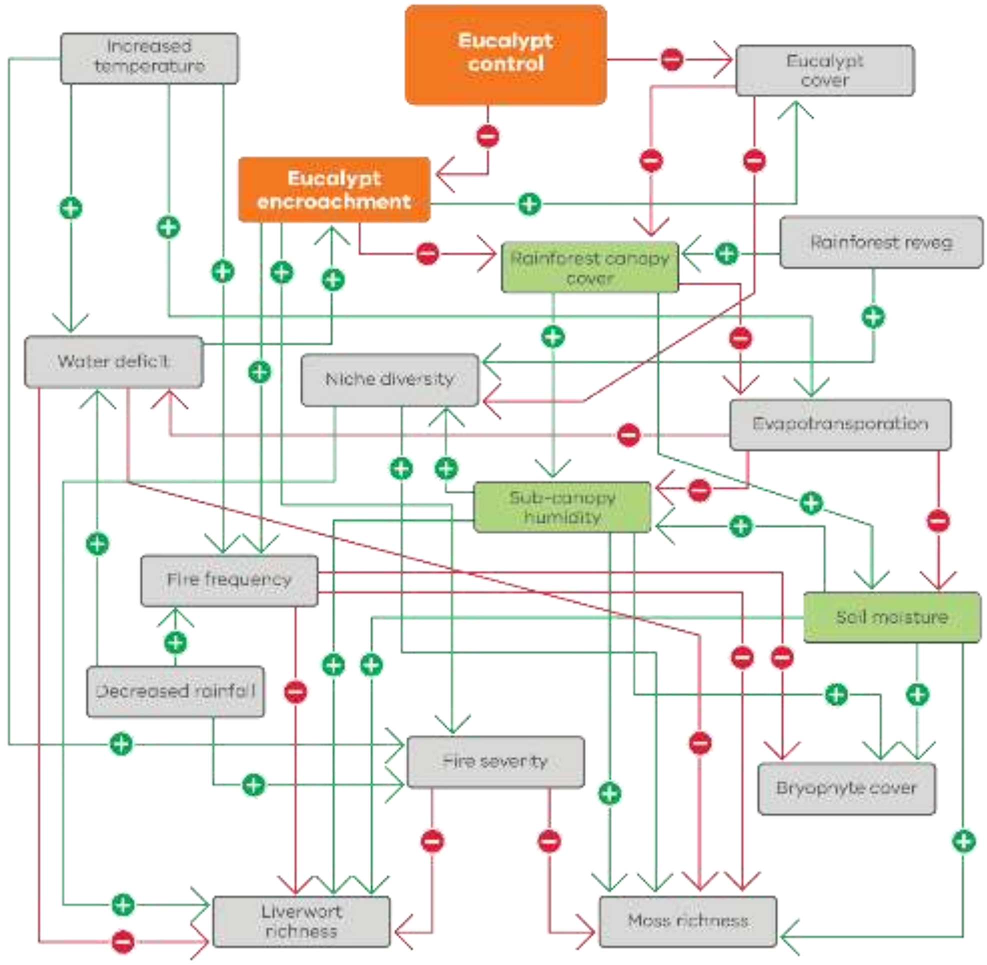

Figure 84. Worst case scenario casual model for loss of rainforest microhabitats for bryophytes caused by encroachment of eucalypts. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Eucalypt encroachment	Eucalypt cover	0.083
1	Eucalypt cover	Niche diversity	0.083
1	Soil moisture	Sub canopy humidity	0.083
4	Eucalypt encroachment	Fire severity	0.042
4	Increased temperature	Fire frequency	0.042
4	Increased temperature	Evapotransporation	0.042
4	Fire severity	Moss richness	0.042
4	Fire frequency	Liverwort richness	0.042
4	Fire frequency	Moss richness	0.042
4	Fire frequency	Bryophyte cover	0.042
4	Decreased rainfall	Water deficit	0.042
4	Decreased rainfall	Fire severity	0.042
4	Decreased rainfall	Fire frequency	0.042
4	Eucalypt control	Eucalypt encroachment	0.042
4	Eucalypt control	Eucalypt cover	0.042
4	Evapotransporation	Soil moisture	0.042
4	Rainforest reveg	Rainforest canopy cover	0.042
4	Rainforest reveg	Niche diversity	0.042
4	Soil moisture	Liverwort richness	0.042
4	Soil moisture	Moss richness	0.042
4	Soil moisture	Bryophyte cover	0.042

Figure 85. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for loss of rainforest microhabitats for bryophytes caused by encroachment of eucalypts

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The highest ranked links eucalypt encroachment on eucalypt cover, eucalypt cover on niche diversity, and soil moisture on sub canopy humidity might be good candidates for research projects, as they each represent the highest reduction in uncertainty of 0.083.

II. Decline in extent and quality of alpine peatland habitats for bryophytes and freshwater algae caused by ungulate pest animals

This model describes the effect of pest ungulate animal control on the cover, species richness, and functional diversity of bryophytes and algae in alpine peatlands. The model explains the impacts of ungulate animals on soil structure, nutrients and water retention, and how this impacts vascular plant and bryophyte / algae components of the system.

Below are the best- and worst-case scenarios for this followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

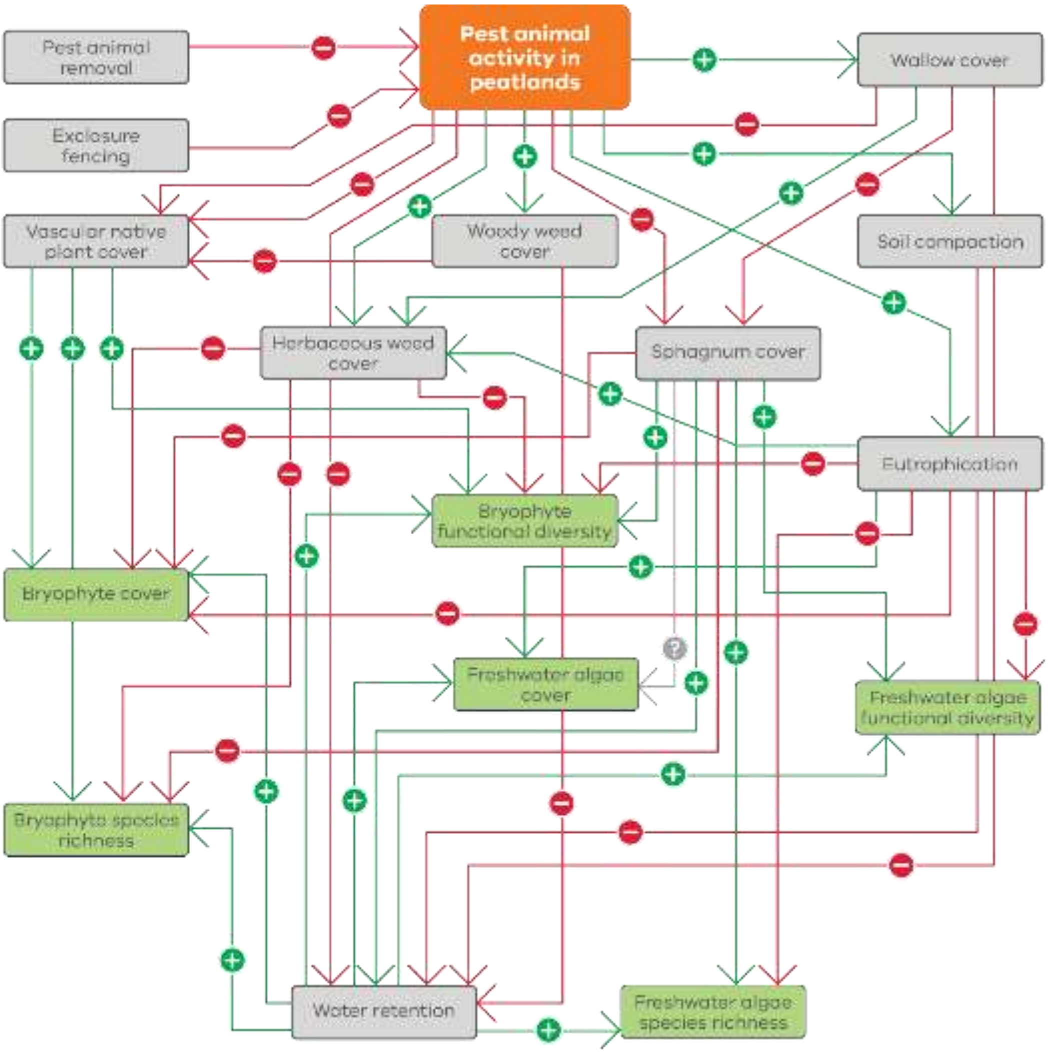

Figure 86. Best case scenario casual model for decline in extent and quality of alpine peatland habitats for bryophytes and freshwater algae caused by ungulate pest animals. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

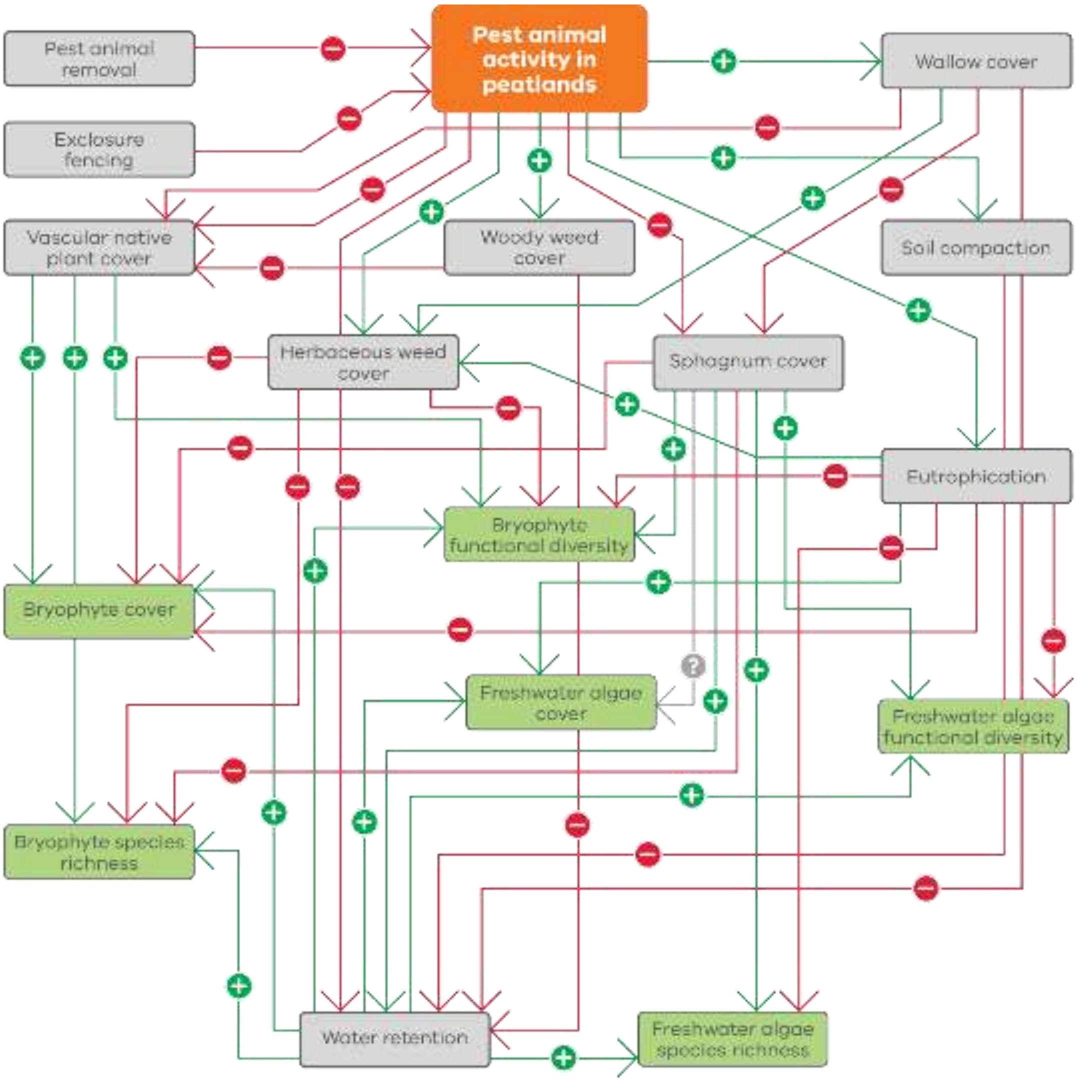

Figure 87. Worst case scenario casual model for decline in extent and quality of alpine peatland habitats for bryophytes and freshwater algae caused by ungulate pest animals. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Water retention	Bryophyte functional diversity	0.306
2	Sphagnum cover	Bryophyte functional diversity	0.294
2	Vascular native plant cover	Bryophyte functional diversity	0.294
2	Herbaceous weed cover	Bryophyte functional diversity	0.294
2	Eutrophication	Bryophyte functional diversity	0.294
6	Sphagnum cover	Water retention	0.023
6	Herbaceous weed cover	Bryophyte cover	0.023
6	Exclosure fencing	Pest animal activity in peatlands	0.023
6	Exclosure fencing	Bryophyte cover	0.023
6	Exclosure fencing	Freshwater algae cover	0.023
6	Eutrophication	Water retention	0.023
6	Water retention	Bryophyte species richness	0.023
6	Water retention	Freshwater algae species richness	0.023
6	Water retention	Freshwater algae functional diversity	0.023
6	Freshwater algae species richness	Water retention	0.023
6	Pest animal activity in peatlands	Sphagnum cover	0.023
6	Pest animal activity in peatlands	Wallow cover	0.023
18	Sphagnum cover	Woody weed cover	0.016
18	Sphagnum cover	Bryophyte species richness	0.016
18	Sphagnum cover	Freshwater algae species richness	0.016
18	Sphagnum cover	Bryophyte cover	0.016
18	Sphagnum cover	Freshwater algae functional diversity	0.016
18	Vascular native plant cover	Woody weed cover	0.016
18	Vascular native plant cover	Bryophyte species richness	0.016

Rank	From	To	Proportional reduction
18	Herbaceous weed cover	Woody weed cover	0.01
18	Herbaceous weed cover	Bryophyte species richness	0.01
18	Woody weed cover	Exclosure fencing	0.01
18	Woody weed cover	Eutrophication	0.01
18	Pest animal removal	Pest animal activity in peatlands	0.01
18	Pest animal removal	Bryophyte cover	0.01
18	Pest animal removal	Freshwater algae cover	0.01
18	Eutrophication	Freshwater algae cover	0.01
18	Wallow cover	Water retention	0.01
18	Pest animal activity in peatlands	Herbaceous weed cover	0.01
18	Pest animal activity in peatlands	Eutrophication	0.01
18	Pest animal activity in peatlands	Soil compaction	0.01
18	Bryophyte cover	Freshwater algae functional diversity	0.01
18	Freshwater algae cover	Freshwater algae functional diversity	0.01
39	Vascular native plant cover	Bryophyte cover	0.00
39	Woody weed cover	Vascular native plant cover	0.00
39	Woody weed cover	Pest animal removal	0.00
39	Woody weed cover	Soil compaction	0.00
39	Woody weed cover	Water retention	0.00
39	Eutrophication	Herbaceous weed cover	0.00
39	Eutrophication	Freshwater algae species richness	0.00
39	Eutrophication	Bryophyte cover	0.00
39	Eutrophication	Freshwater algae functional diversity	0.00
39	Soil compaction	Water retention	0.00
39	Water retention	Bryophyte cover	0.00
39	Water retention	Freshwater algae cover	0.00
39	Bryophyte species richness	Water retention	0.00
39	Wallow cover	Sphagnum cover	0.00
39	Wallow cover	Vascular native plant cover	0.00
39	Wallow cover	Herbaceous weed cover	0.00
39	Pest animal activity in peatlands	Vascular native plant cover	0.00
39	Pest animal activity in peatlands	Woody weed cover	0.00

Figure 88. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for decline in extent and quality of alpine peatland habitats for bryophytes and freshwater algae caused by ungulate pest animals

The highest ranked links were the following on bryophyte functional diversity: water retention, sphagnum cover, vascular native plant cover, herbaceous weed cover, and eutrophication. These might be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.308 for the first link, and 0.294 for the other four.

III. Decline of seasonal herbaceous wetlands and associated impacts on freshwater algae caused by land management activities

This model describes the effects of cropping, burning, and grazing animal management on freshwater algae that occupy seasonal herbaceous wetlands. It includes the effects of integrated use of controlled stock grazing, controlled burning and selective herbicide application to mitigate threats from weeds, excess nutrients and high intensity wildfire.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

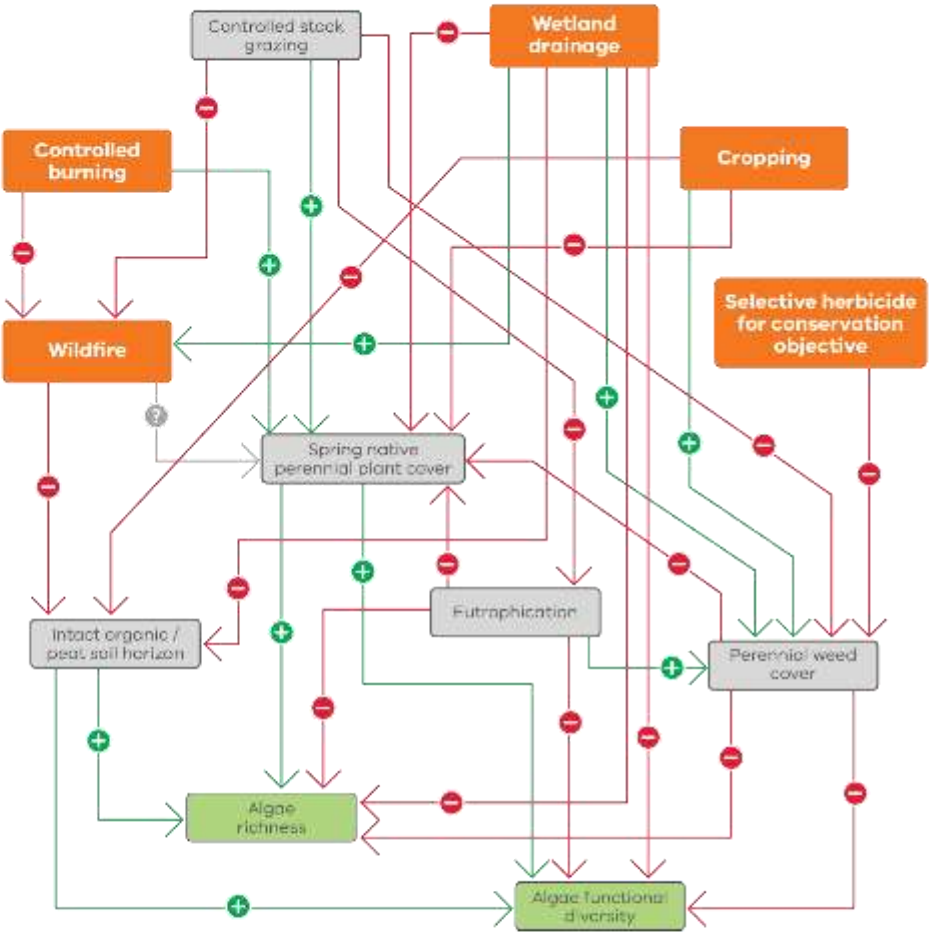

Figure 89. Best case scenario casual model for decline of seasonal herbaceous wetlands and associated impacts on freshwater algae caused by land management activities. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

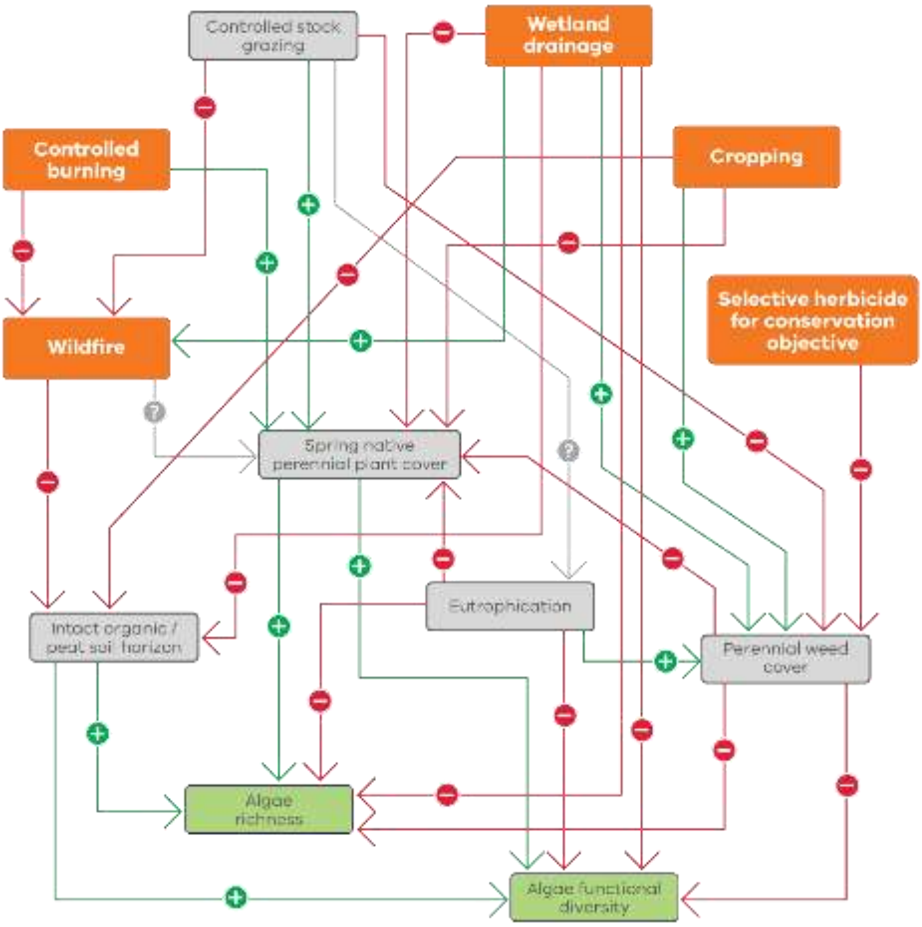

Figure 90. Worst case scenario casual model for decline of seasonal herbaceous wetlands and associated impacts on freshwater algae caused by land management activities. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Spring native perennial plant cover	Algae richness	0.127
1	Spring native perennial plant cover	Algae functional diversity	0.127
3	Controlled stock grazing	Perennial weed cover	0.108
4	Wetland drainage	Wildfire	0.064
4	Wetland drainage	Perennial weed cover	0.064
4	Perennial weed cover	Algae functional diversity	0.064
4	Selective herbicide for conservation objective	Perennial weed cover	0.064
4	Eutrophication	Algae richness	0.064
4	Eutrophication	Algae functional diversity	0.064
4	Intact organic peat soil horizon	Algae richness	0.064
4	Intact organic peat soil horizon	Algae functional diversity	0.064
4	Controlled stock grazing	Spring native perennial plant cover	0.064
4	Controlled stock grazing	Eutrophication	0.064

Figure 91. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for decline of seasonal herbaceous wetlands and associated impacts on freshwater algae caused by land management activities

The highest ranked links were spring native perennial plant cover on algae richness and functional diversity (reduction in uncertainty of 0.127), and controlled stock grazing on perennial weed cover (0.108). These might be good candidates for research projects, as they represent the highest reduction in uncertainty.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: *Bartramia subsymmetrica*

State advisory listed, endangered, FFG Act listed

Number of experts: 3

Locations:

Bogong High Plains

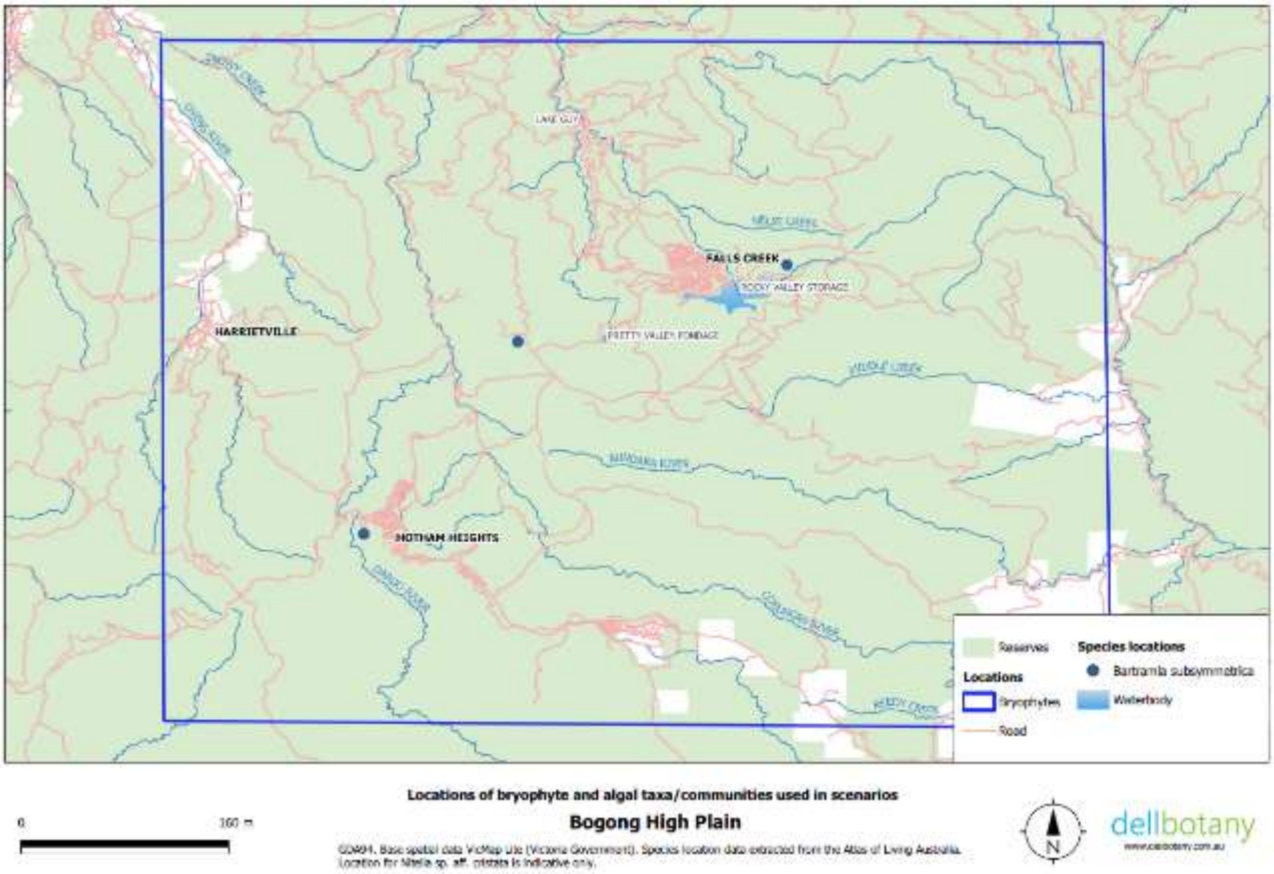

Figure 92. Locations for *Bartramia subsymmetrica* actions

#	Actions:	
	No action	As described.
1	Ungulate pest animal control	Reduction of pest ungulate animal density within the landscape to negligible level. This includes the removal of animals (population reduction) rather than the control of their movement or other control measure to reduce impacts. Control may include combinations of culling and or capture. Bogong High Plains – targeted deer, horse and cattle control. Within the sub-catchment of the target bryophyte: undertake control to reduce combined pest animal density by 50% at year 5 and 80% by year 10. Determine density estimates with suitable monitoring method.
2	Exclosure fencing at known populations	Bogong High Plains - Exclosure fencing is a contiguous barrier that prevents target pest animals from accessing defined areas. It is assumed for this purpose that an exclosure is 100% effective at preventing access for the target pest animal. Fences typically comprise 2 m tall post and wire mesh barriers and may encompass 0.5–3 hectares. For this exercise, all known *Bartramia subsymmetrica* sites would be fenced.
3	Weed control	Weed control actions are varied depending on the circumstances. The actions are focused on tractable threats which are typically woody weeds. Herbaceous weed control may occur where it targets certain high threat species at a location e.g. Orange Hawkweed. Within the location area, reduce woody weeds to <1% cover. Reduce high threat herbaceous weeds to <5% cover in the immediate vicinity of target bryophyte populations. • Bogong High Plains – Willow control, other woody weeds and selected herbaceous weeds.
4	Propagation and establishment in new sites	Ex situ propagation of bryophytes is rarely implemented for conservation; however methods have been developed overseas for potential use in Australia. This action involves the propagation of material from spores or asexual material and re-introduction of gametophytes to unoccupied substrates, within and around known sites. It assumes a protocol is in place to manage site contamination and other threats. •Micro-siting of recipient sites/substrates will be determined with niche modelling. • Unoccupied habitats would be identified for introductions within areas of equal or greater security e.g. National Parks • Bogong High Plains – establish 200 tubes of *Bartramia subsymmetrica* at each of 10 new peatland sites, minimum 0.5 km apart on the Bogong High Plains. A tube is a 10 x 10 cm patch containing multiple gametophytes.

Based on expert assessment the benefit of each action at each location for this species is as follows:

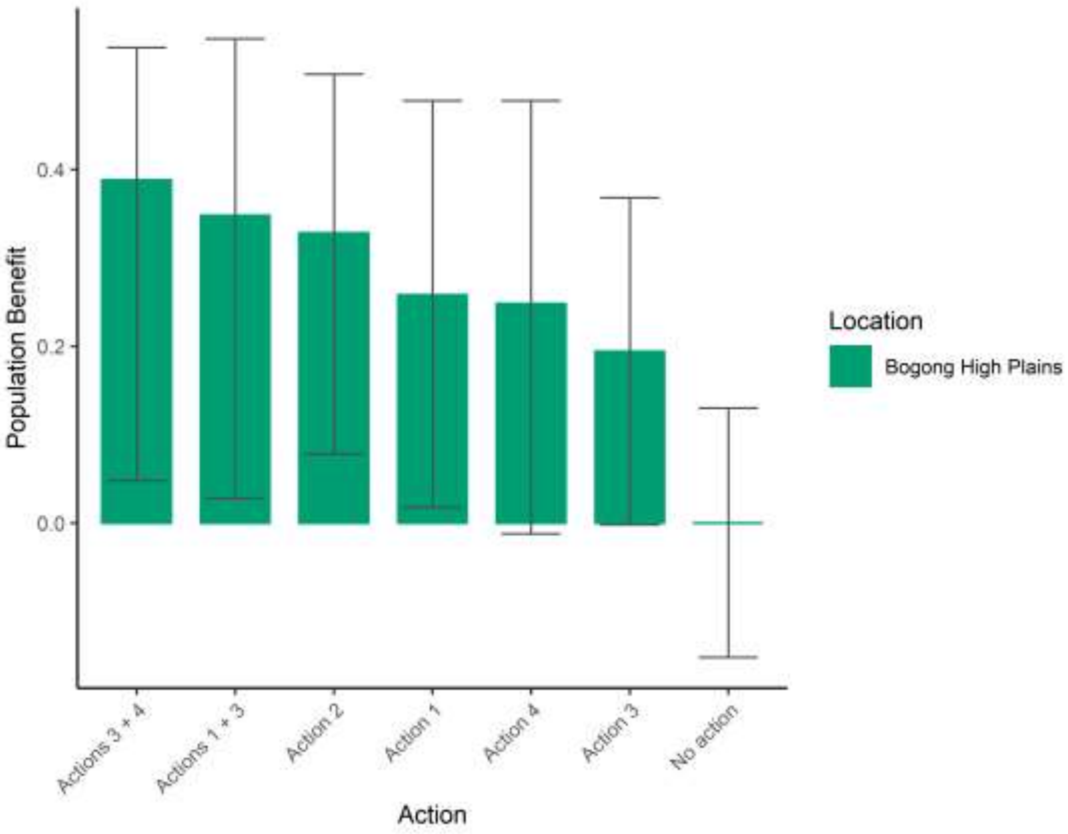

Figure 93. Mean change in *Bartramia subsymmetrica* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

This species shows a progressive rank in benefit for each action or combination considered. While weed control is the least beneficial in isolation, it improves probability of persistence when combined with propagation and establishment in new sites (action 4) and ungulate pest control (action 1). Exclosure fencing (action 2) is the highest-ranking single action for this species at this site.

Species: *Calomnion complanatum*

State advisory listed, endangered, FFG Act listed

Number of experts: 3

Locations:

Wilsons Promontory

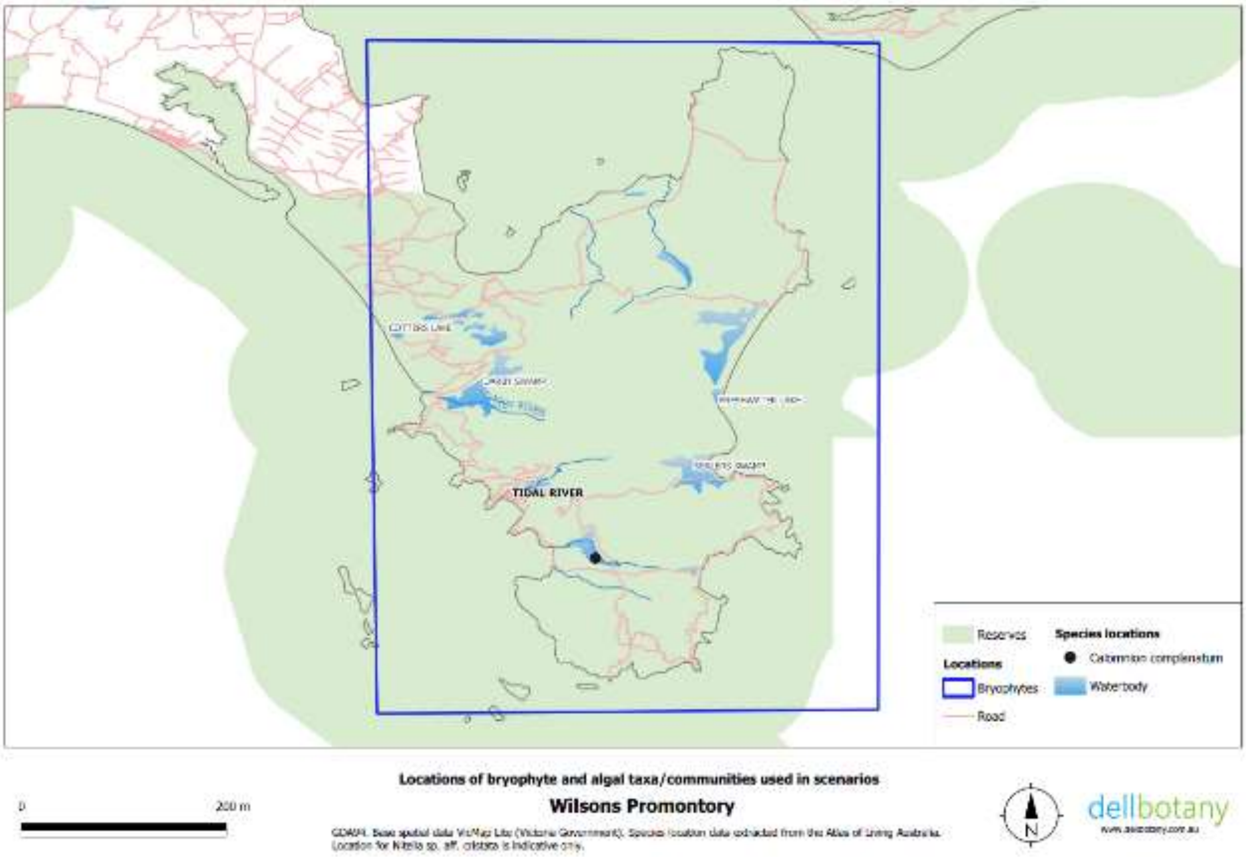

Figure 94. Locations for *Calomnion complanatum* actions.

#	Actions:	
	No action	As described.
1	Weed control	Weed control actions are varied depending on the circumstances. The actions are focused on tractable threats which are typically woody weeds. Herbaceous weed control may occur where it targets certain high threat species at a location. Within the location area, reduce woody weeds to <1% cover. Reduce high threat herbaceous weeds to <5% cover in the immediate vicinity of target bryophyte populations. Wilsons Promontory – Thinning of *Leptospermum laevigatum* (Coast Tea tree) in scrub up to 100 m from populations (<20% total cover). Control of non-indigenous woody weeds.
2	Habitat restoration	This action includes the manipulation of vegetation structure or substrate distribution to promote site climate conditions and microhabitat for relevant bryophytes. • East Gippsland and Wilsons Promontory - For rainforest scenarios, it includes buffer planting of broadleaf indigenous shrubs and canopy species to 70% total site cover, with the objective to limit eucalypt encroachment, displace weeds and maintain shade and humidity within wet gullies. It has longer term objectives to increase the width of rainforest patches where conditions allow. Each buffer planting will extend for 100 m along the rainforest ecotone adjacent to populations. Habitat restoration does not include additional weed control.
3	Propagation and establishment in new sites	*Ex situ* propagation of bryophytes is rarely implemented for conservation; however, methods have been developed overseas for potential use in Australia. This action involves the propagation of material from spores or asexual material and re-introduction of gametophytes to unoccupied substrates, within and around known sites. It assumes a protocol is in place to manage site contamination and other threats. • Micro-siting of recipient sites/substrates will be determined with niche modelling. • Unoccupied habitats would be identified for introductions within areas of equal or greater security e.g. National Parks. • Wilsons Promontory and Baw Baw South Face - establish 100 *Calomnion complanatum* tubes on 30 tree fern trunks each at two other rainforest gullies. A tube is a 10 x 10 cm patch containing multiple gametophytes.
4	Ungulate pest animal control	Reduction of pest ungulate animal density within the landscape to negligible level. This includes the removal of animals (population reduction) rather than the control of their movement or other control measure to reduce impacts. Control may include combinations of culling and or capture.

Based on expert assessment the benefit of each action at each location for this species is as follows:

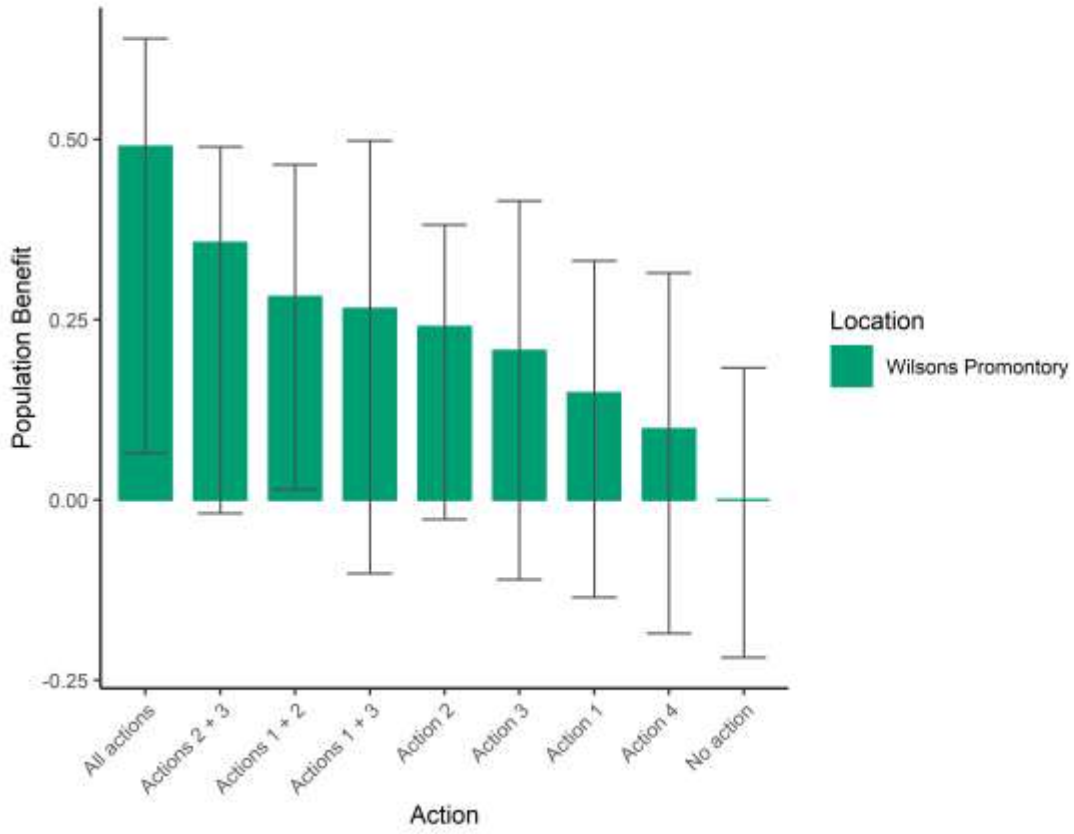

Figure 95. Mean change in *Calomnion complanatum* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

While this species shows a clear preference for all actions, other combinations or single actions demonstrate a progressive rank in benefit. Propagation to new sites (action 3) and habitat restoration at existing sites (action 2) are ranked highly, with restoration being the highest-ranking single action for this species.

Species: ***Treubia tasmanica, Triandrophyllum subtrifidum & Calomnion complanatum***

All state advisory listed, endangered, FFG Act listed

Number of experts: 6

Locations:

Baw Baw South Face

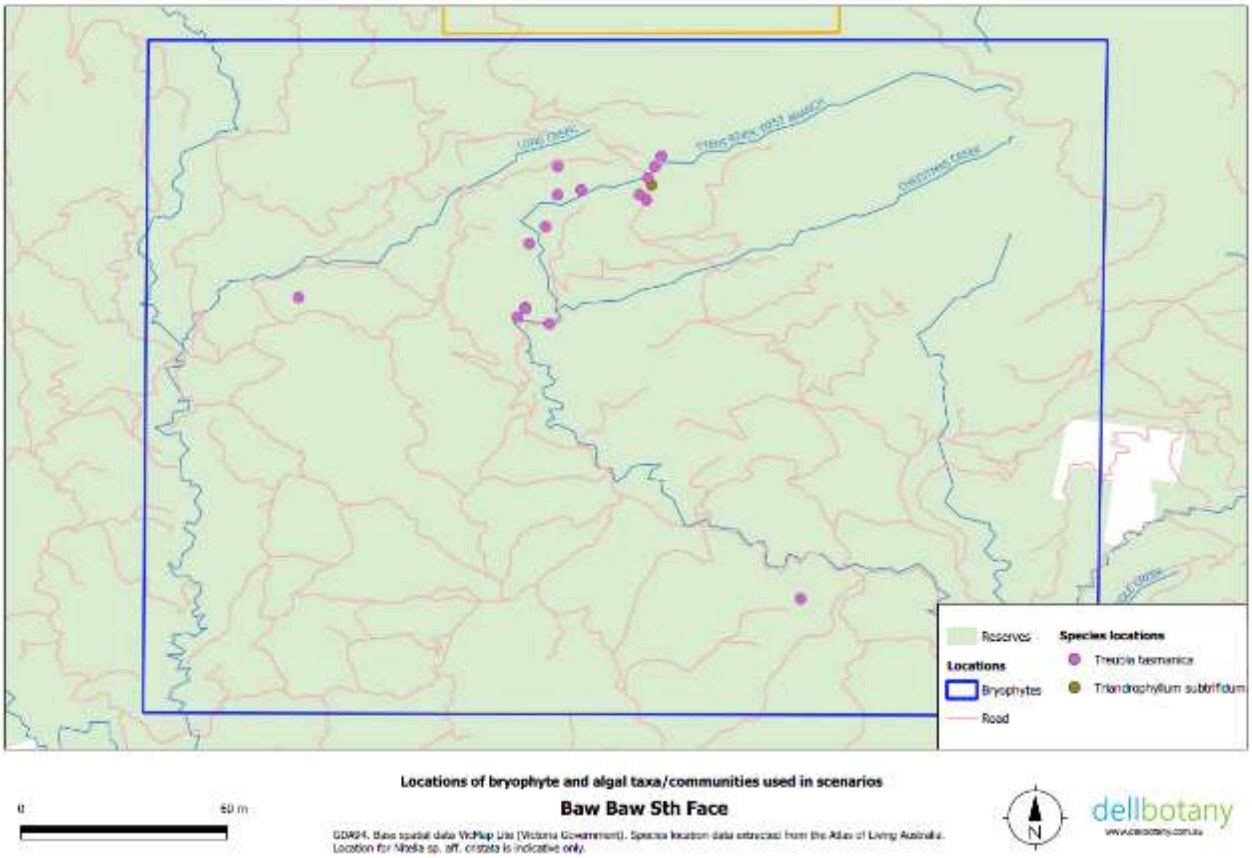

Figure 96. Locations for *Treubia tasmanica, Triandrophyllum subtrifidum* & *Calomnion complanatum* actions.

#	Actions:	
	No action	As described.
1	Strategic burns to protect habitat	This action includes only the use of fuel reduction burns - the burning of vegetation at tolerable intervals, in landscape positions that are strategically important for reducing impacts to wet forest gullies. Fuel reduction burns in the Tanjil foothills to south west of populations. 50% burned in a mosaic over 10 years. Fuel management burns in forestry coups surrounding known populations. It does not include opportunistic fire suppression during wildfires i.e. only strategic actions.
2	Weed control	Weed control actions are varied depending on the circumstances. The actions are focused on tractable threats which are typically woody weeds. Herbaceous weed control may occur where it targets certain high threat species at a location. Within the location area, reduce woody weeds to <1% cover. Reduce high threat herbaceous weeds to <5% cover in the immediate vicinity of target bryophyte populations. • Baw Baw South Face - Gullies amongst landscapes managed for forestry would be subject to roadside and forestry coup integrated weed management. This includes drainage improvement to manage stormwater runoff into creeks and minimise sediment and weed seed deposition. It also includes controlling the spread of eucalypt seedlings which originate from forestry cultivation. Other control is focused on *Rubus fruiticosus* sp. agg. (Blackberry).
3	Propagation and establishment at new sites	*Ex situ* propagation of bryophytes is rarely implemented for conservation; however, methods have been developed overseas for potential use in Australia. This action involves the propagation of material from spores or asexual material and re-introduction of gametophytes to unoccupied substrates, within and around known sites. It assumes a protocol is in place to manage site contamination and other threats. •Micro-siting of recipient sites/substrates will be determined with niche modelling. • Unoccupied habitats would be identified for introductions within areas of equal or greater security e.g. National Parks. • Baw Baw South Face – establish 100 *Treubia tasmanica* and 100 *Triandrophyllum subtrifidum* tubes in two adjacent CTRF gullies. Planted over 200 m length at each gully. A tube is a 10 x 10 cm patch containing multiple gametophytes.
4	Myrtle Wilt management	Buffer planting on creek intersections with road and track crossings, to reduce the incidence of edge damage to *Nothofagus cunninghamii* and decline of Myrtle Wilt. Establish 200 m exclusive management zones for biodiversity, laterally from major stream centre lines within Tanjil Bren and Erica State Forests (400 m total buffer).
5	Habitat restoration	This action includes the manipulation of vegetation structure or substrate distribution to promote site climate conditions and microhabitat for relevant bryophytes. • Baw Baw South Face – Broadleaf shrub and rainforest canopy planting as per East Gippsland (below). At this location it also includes the translocation of *Dicksonia antarctica* (Soft Treefern) to suitable areas where lost from past disturbance. *D. antarctica* sourced from nearby forestry coups, to increase the area of available growing substrate. The

		moss *C. complanatum* is +/-an obligate epiphyte on tree ferns. Target 100 *D. Antarctica* translocated. Habitat restoration does not include additional weed control.

Based on expert assessment the benefit of each action at each location for this species is as follows:

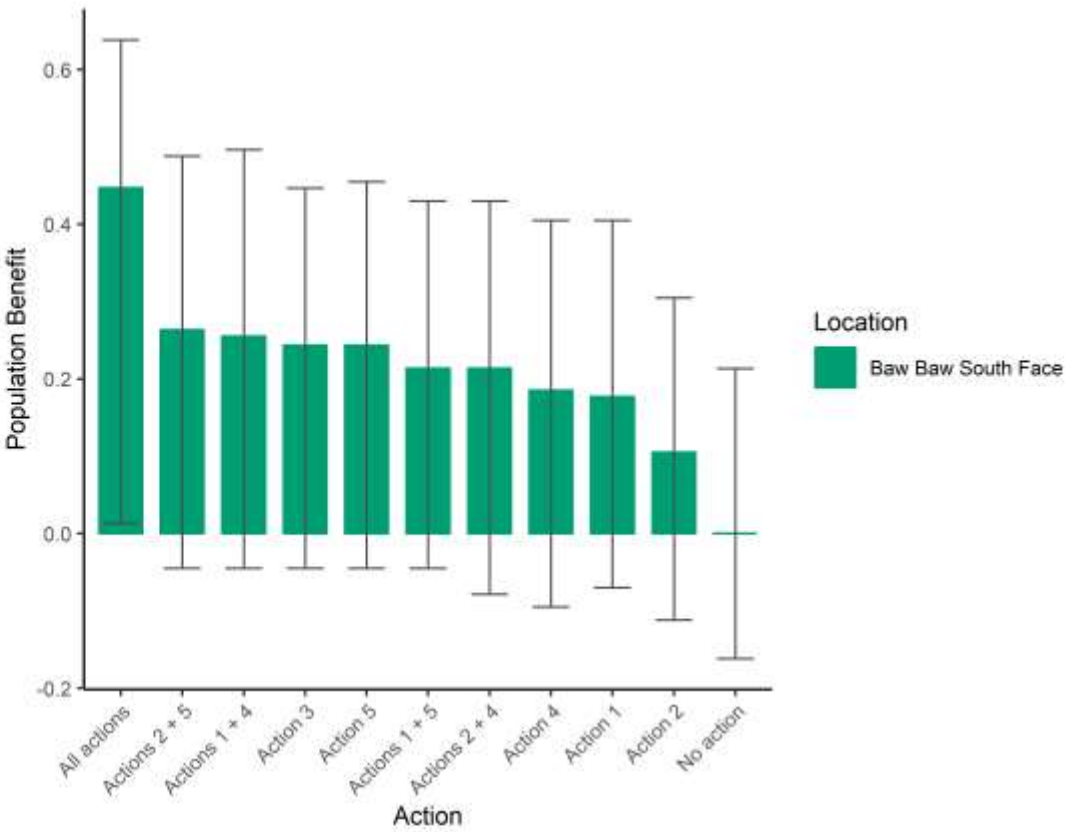

Figure 97. Mean change in *Treubia tasmanica, Triandrophyllum subtrifidum & Calomnion complanatum* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

While this species would benefit from all actions, other combinations or single actions demonstrate a progressive rank in benefit of around 0.2. Propagation to new sites (action 3) and habitat restoration at existing sites (action 5) are the highest ranked single actions. Myrtle Wilt management (action 4) is notably more beneficial when combined with fuel reduction burns (action 1) and weed control (action 2).

Species: ***Adelanthus bisetulus***

Advisory listed rare

Number of experts: 3

Locations:

Grampians Ranges

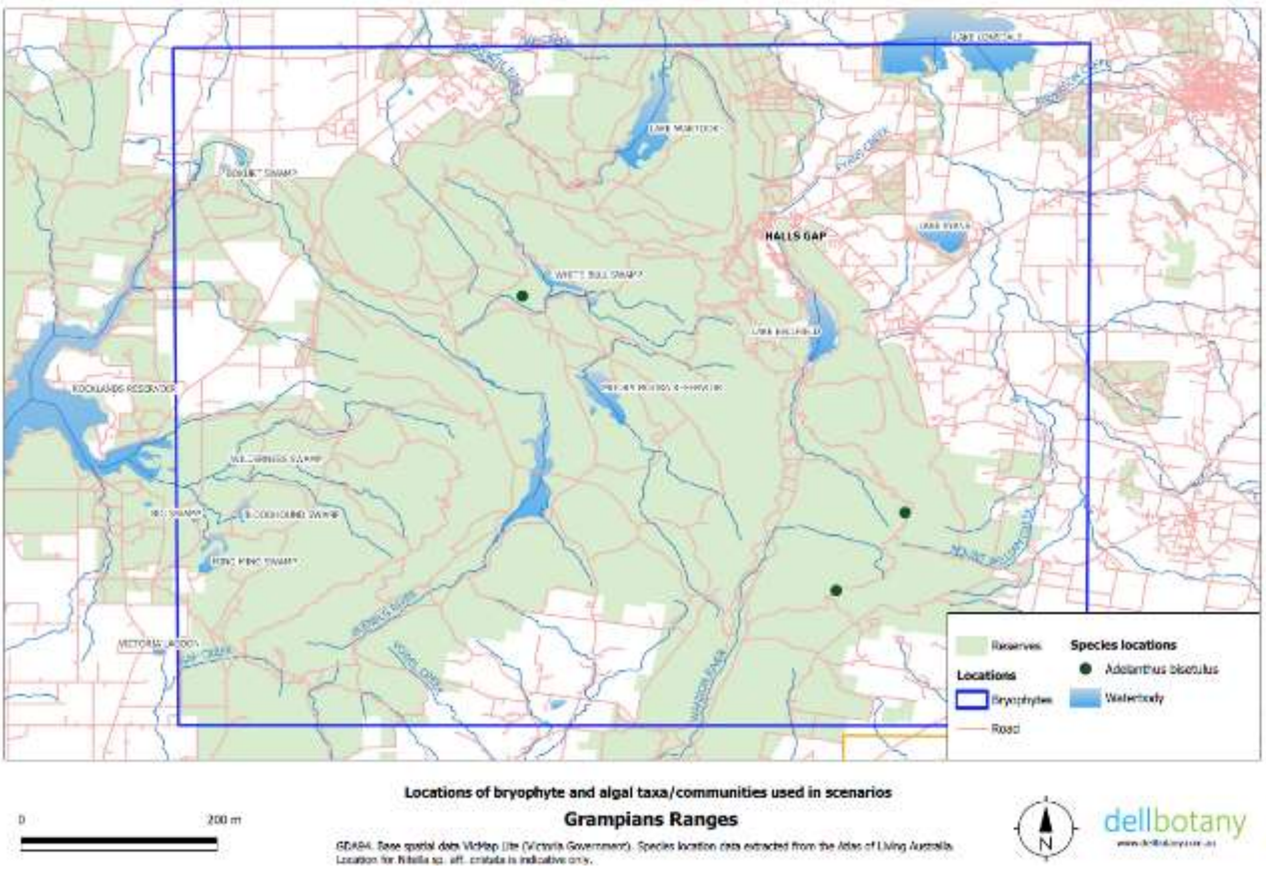

Figure 98. Locations for *Adelanthus bisetulus* actions.

#	Actions:	
	No action	As described.
1	Ungulate pest animal control - goats	Reduction of pest ungulate animal density within the landscape to negligible level. This includes the removal of animals (population reduction) rather than the control of their movement or other control measure to reduce impacts. Control may include combinations of culling and or capture. Within the sub-catchment of the target bryophyte: undertake control to reduce combined pest animal density by 50% at year 5 and 80% by year 10. Determine density estimates with suitable monitoring method.
2	Weed control	Weed control actions are varied depending on the circumstances. The actions are focused on tractable threats which are typically woody weeds. Herbaceous weed control may occur where it targets certain high threat species at a location. Within the location area, reduce woody weeds to <1% cover. Reduce high threat herbaceous weeds to <5% cover in the immediate vicinity of target bryophyte populations. • Grampians Ranges – *Acacia longifolia* (Sallow Wattle) and other woody weed control.
3	Exclosure fencing	Exclosure fencing would be built to specification to prevent goat and human access into sites. Five exclosure sites of 1000 m^2 each would be established over the extent of occurrence of Mt William populations of *Adelanthus bisetulus*.

Based on expert assessment the benefit of each action at each location for this species is as follows:

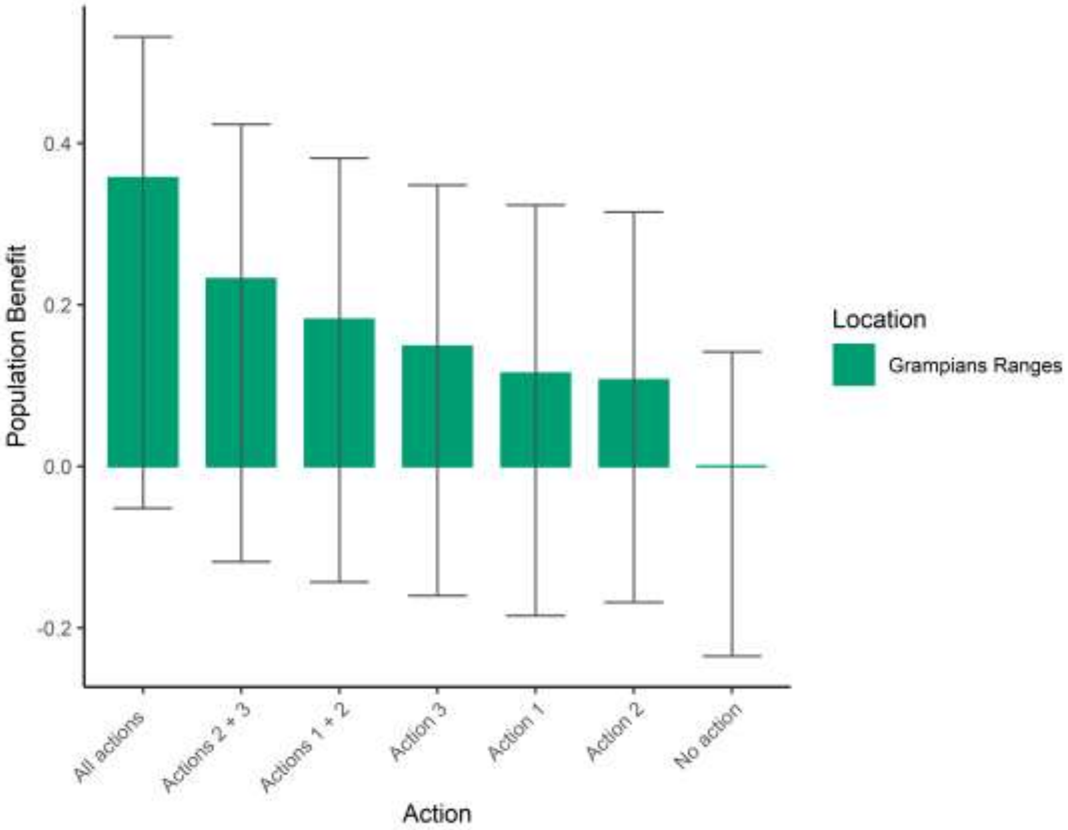

Figure 99. Mean change in *Adelanthus bisetulus* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

This species shows a clear preference for all actions. Other combinations or single actions demonstrate a progressively decreasing rank in benefit from around 0.2. Exclosure fencing (action 3) is the highest ranked single action but is aided by more appropriate or strategic weed control.

Species: (i) *Bazzania hochstetteri* & (ii) *Adelanthus bisetulus*

(i) State advisory listed vulnerable, FFG Act listed

(ii) Advisory listed rare

Number of experts: 3

Locations:

East Gippsland

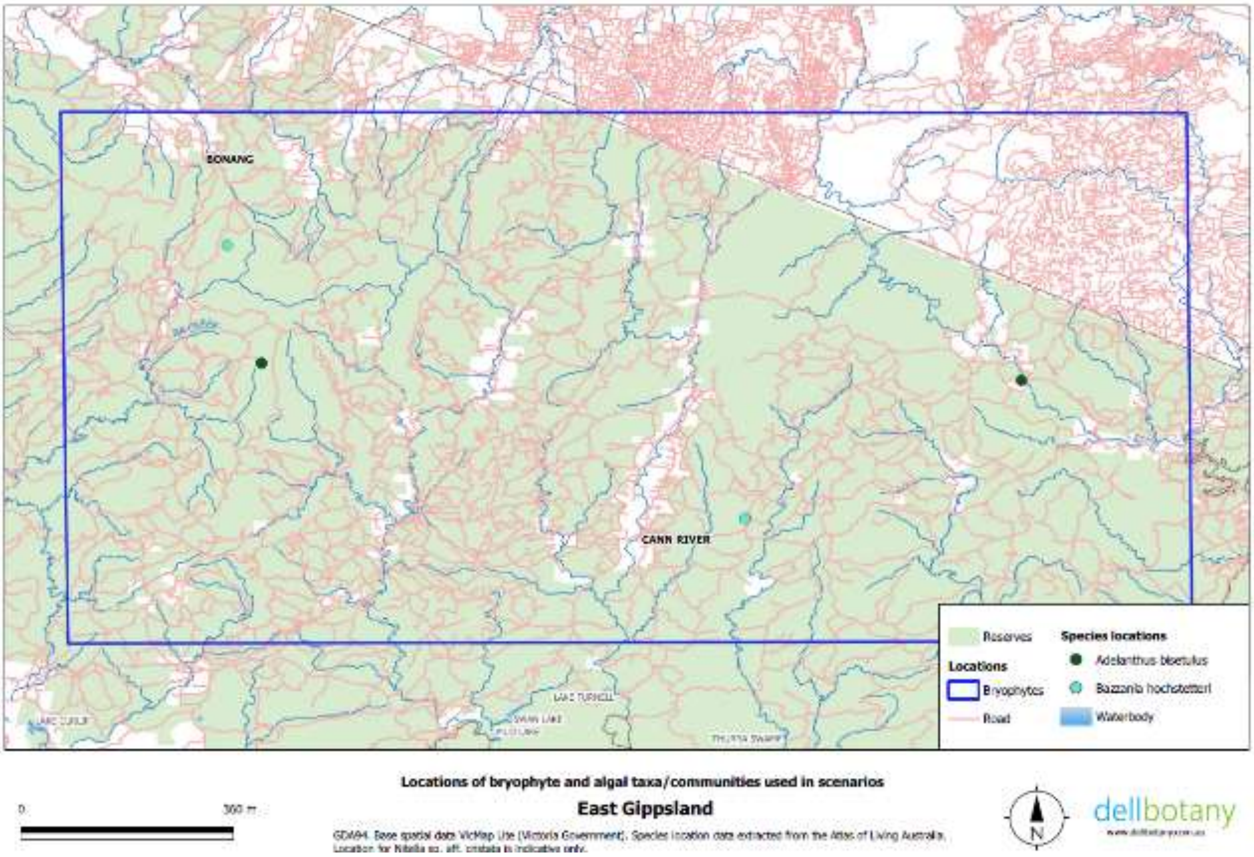

Figure 100. Locations for *Bazzania hochstetteri* & *Adelanthus bisetulus* actions.

#	Actions:	
	No action	As described.
1	Ungulate pest animal control – deer/pigs	Reduction of pest ungulate animal density within the landscape to negligible level. This includes the removal of animals (population reduction) rather than the control of their movement or other control measure to reduce impacts. Control may include combinations of culling and or capture. Within the sub-catchment of the target bryophyte: undertake control to reduce combined pest animal density by 50% at year 5 and 80% by year 10. Determine density estimates with suitable monitoring method.
2	Weed control	Weed control actions are varied depending on the circumstances. The actions are focused on tractable threats which are typically woody weeds. Herbaceous weed control may occur where it targets certain high threat species at a location. Within the location area, reduce woody weeds to <1% cover. Reduce high threat herbaceous weeds to <5% cover in the immediate vicinity of target bryophyte populations. East Gippsland – Blackberry, other woody weeds and selected herbaceous weeds.
3	Eucalypt removal	Remove eucalyptus saplings to 5 m tall within 20 m of rainforest patch edge. Extent to 1 km from known sites for target bryophytes, on each side of the gully. Fell eucalyptus trees within rainforest patch which have a dbh of <10 cm dbh. Repeated every four years.
4	Habitat restoration	This action includes the manipulation of vegetation structure or substrate distribution to promote site climate conditions and microhabitat for relevant bryophytes. • East Gippsland and Wilson's Promontory - For rainforest scenarios, it includes buffer planting of broadleaf indigenous shrubs and canopy species to 70% total site cover, with the objective to limit eucalypt encroachment, displace weeds and maintain shade and humidity within wet gullies. It has longer term objectives to increase the width of rainforest patches where conditions allow. Each buffer planting will extend for 100 m along the rainforest ecotone adjacent to populations.

Based on expert assessment the benefit of each action at each location for this species is as follows:

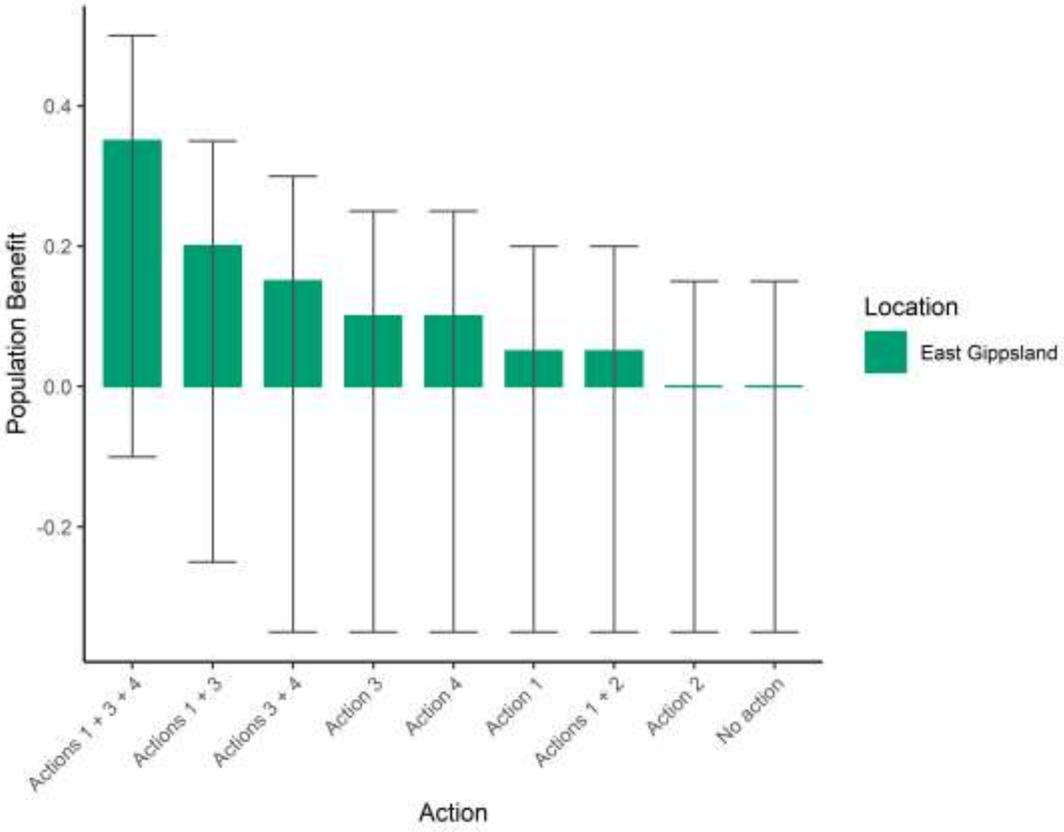

Figure 101. Mean change in *Bazzania hochstetteri* & *Adelanthus bisetulus* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Expert opinion for this species demonstrates large variability in the perceived benefit, with some respondents estimating a disbenefit from each action or combination. This may be because the actions chosen are inappropriate, or that the species likelihood of persistence is too poor to be remedied. Despite this, experts overall anticipated some benefit with eucalypt removal (action 3), ideally in combination with ungulate pest animal control (action 1) and habitat restoration (action 4) ranked highest.

Species: ***Chara karolii***

Number of experts: 6

Locations:

East Grampians wetlands cluster

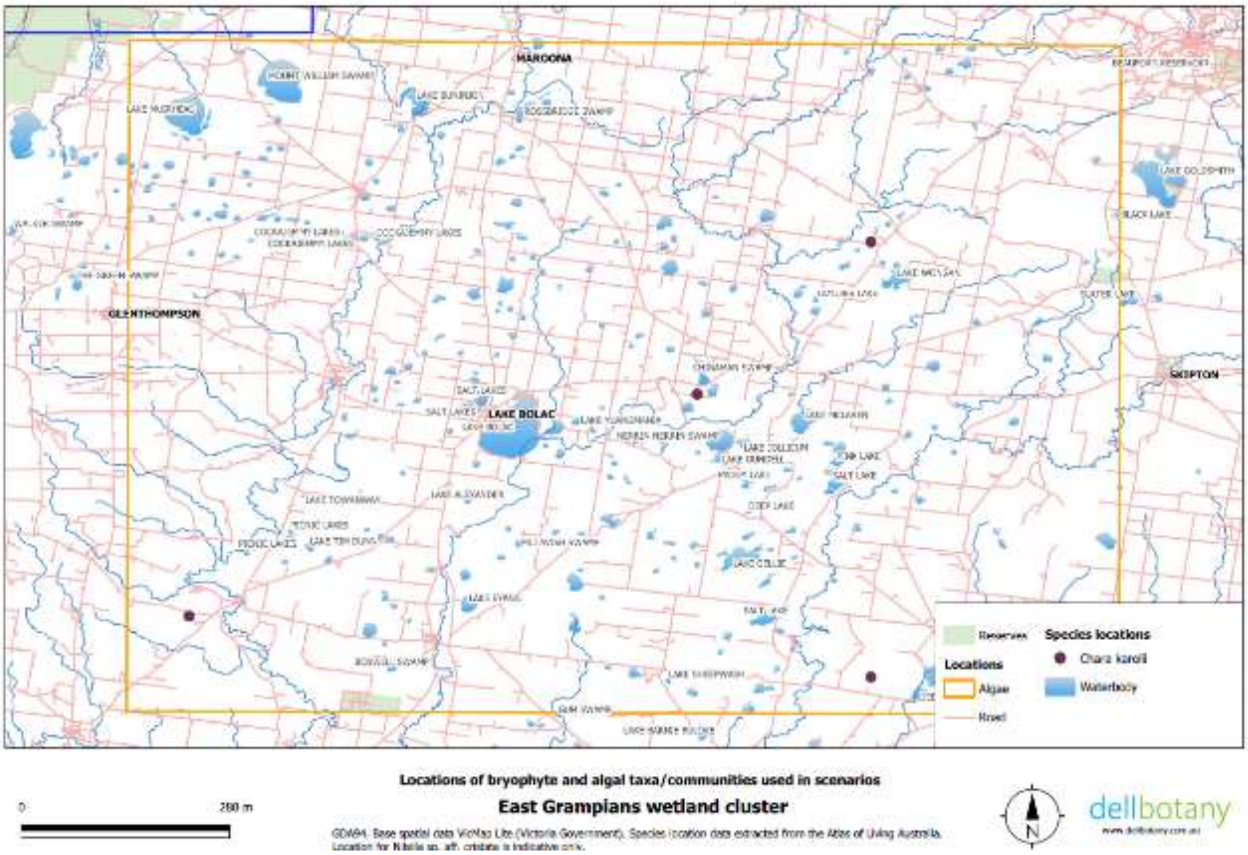

Figure 102. Locations for *Chara karolii* actions.

#	Actions:	
	No action	As described.
1	Cessation of cropping	Cropping is a main treatment which includes the use of various treatments in combination. All of these must be considered. They include rotary hoeing, planting of crops, application of preemergent herbicide, application of post emergent herbicide, application of insecticides and/or application of fertiliser. The action is to remove cropping over the area of seasonal wetlands and within a buffer to 40 m of their mapped perimeter.
2	Seasonal grazing management	This action involves the use of moderate intensity sheep grazing from December to March each year. Grazing by stock is excluded for the remainder of year (fenced).
3	Strategic burns to protect habitat	Intense wildfire can remove soil surface biota and terrestrial algae, destroy mires and bogs, and remove vegetation and seed bank from shallow wetlands when they are dry. This action is to control burn in buffers around notable or vulnerable habitats including riparian zones, with the aim to reduce the likelihood and intensity of wildfire. Burning is undertaken at 5-year intervals, at 30% of wetlands within each location.
4	Cessation of wetland drainage	The draining of shallow wetlands destroys algal habitat and populations. Preventing the drainage of freshwater wetland in agricultural areas aims to further protect the majority of algal habitat in these systems. The action requires the cessation of wetland drainage caused by the installation of drains or pumping for agricultural purposes.

Based on expert assessment the benefit of each action at each location for this species is as follows:

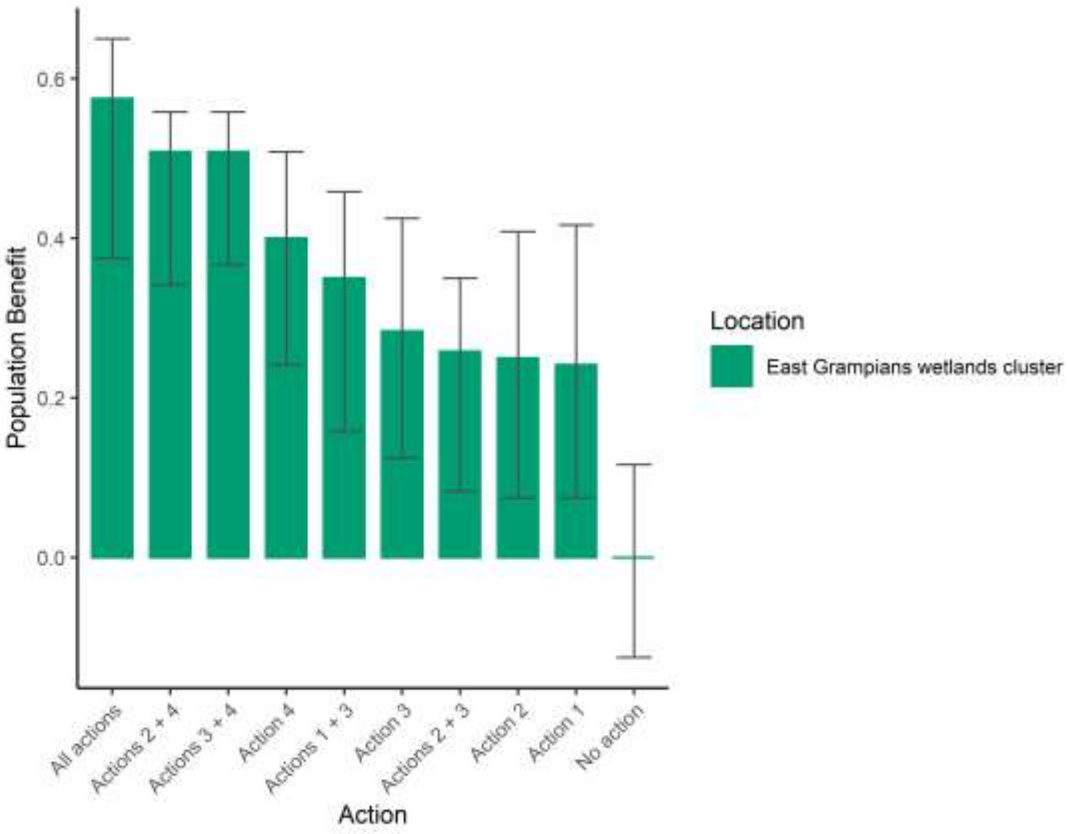

Figure 103. Mean change in *Chara karolii* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Actions for this species have been given a relatively high benefit estimate, particularly cessation of wetland drainage (action 4). Benefit is boosted when paired with seasonal grazing management (action 2) or strategic burns to protect habitat (action 3).

Species: ***Nitella sp. aff. cristata***

Number of experts: 3

Locations:

West Wimmera wetlands cluster

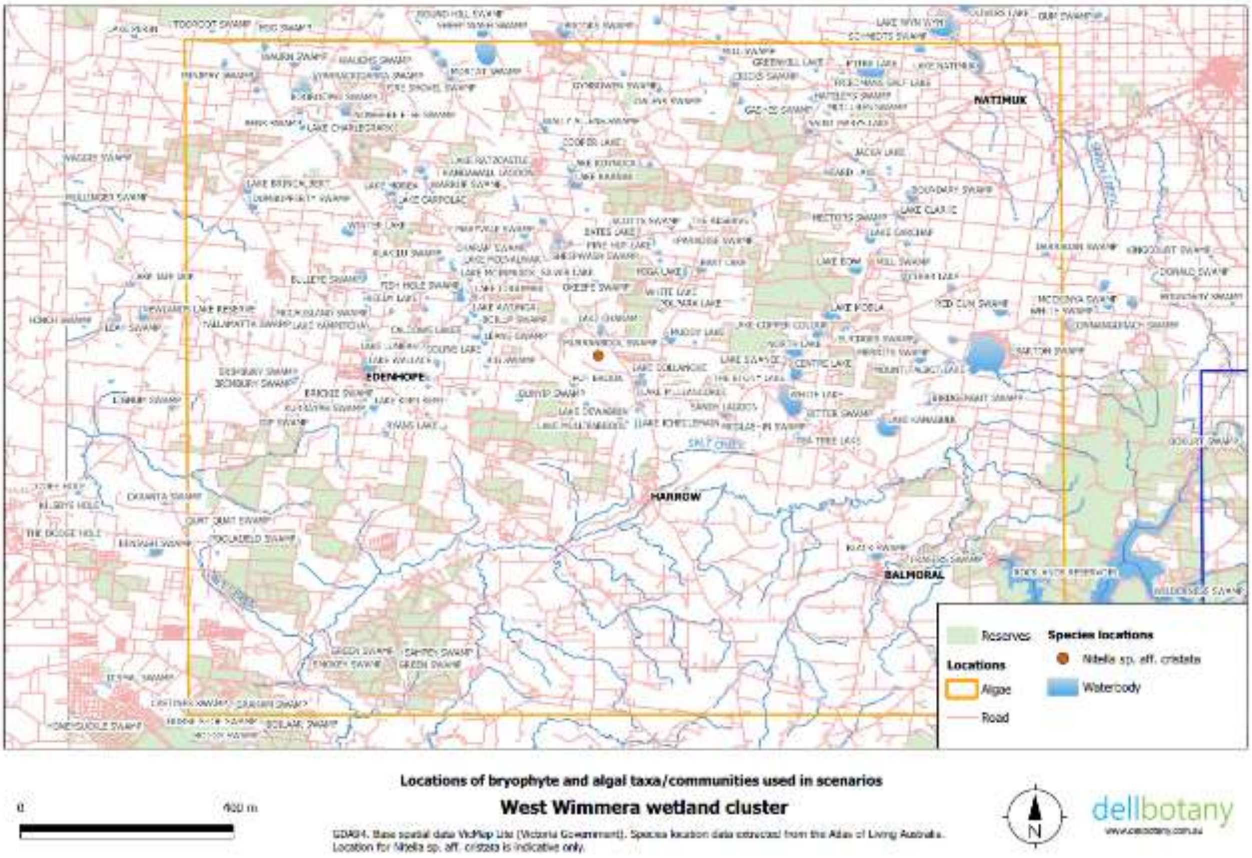

Figure 104. Locations for *Nitella* sp. aff. *cristata* actions.

#	Actions:	
	No action	As described.
1	Cessation of cropping	Cropping is a main treatment which includes the use of various treatments in combination. All of these must be considered. They

		include rotary hoeing, planting of crops, application of preemergent herbicide, application of post emergent herbicide, application of insecticides and/or application of fertiliser. The action is to remove cropping over the area of seasonal wetlands and within a buffer to 40 m of their mapped perimeter.
2	Seasonal grazing management	This action involves the use of moderate intensity sheep grazing from December to March each year. Grazing by stock is excluded for the remainder of year (fenced).
3	Strategic burns to protect habitat	Intense wildfire can remove soil surface biota and terrestrial algae, destroy mires and bogs, and remove vegetation and seed bank from shallow wetlands when they are dry. This action is to control burn in buffers around notable or vulnerable habitats including riparian zones, with the aim to reduce the likelihood and intensity of wildfire. Burning is undertaken at 5-year intervals, at 30% of wetlands within each location.
4	Exclude stock	The freshwater habitats that contain algae are vulnerable to eutrophication, turbidity, erosion and disturbance by feral (horses, deer, pigs) and domestic (sheep, cattle) animals. Restricting animal access to the riparian strips and buffers of these systems by fencing aims to reduce the likelihood of eutrophication, erosion and turbidity in these systems. This action prevents all stock access throughout the year.
5	Weed control	Control of all woody weeds in seasonal wetlands to negligible cover (<1% total). Control of high threat herbaceous weeds such as *Nassella* species and *Phalaris aquatica* to <20% combined cover.

Based on expert assessment the benefit of each action at each location for this species is as follows:

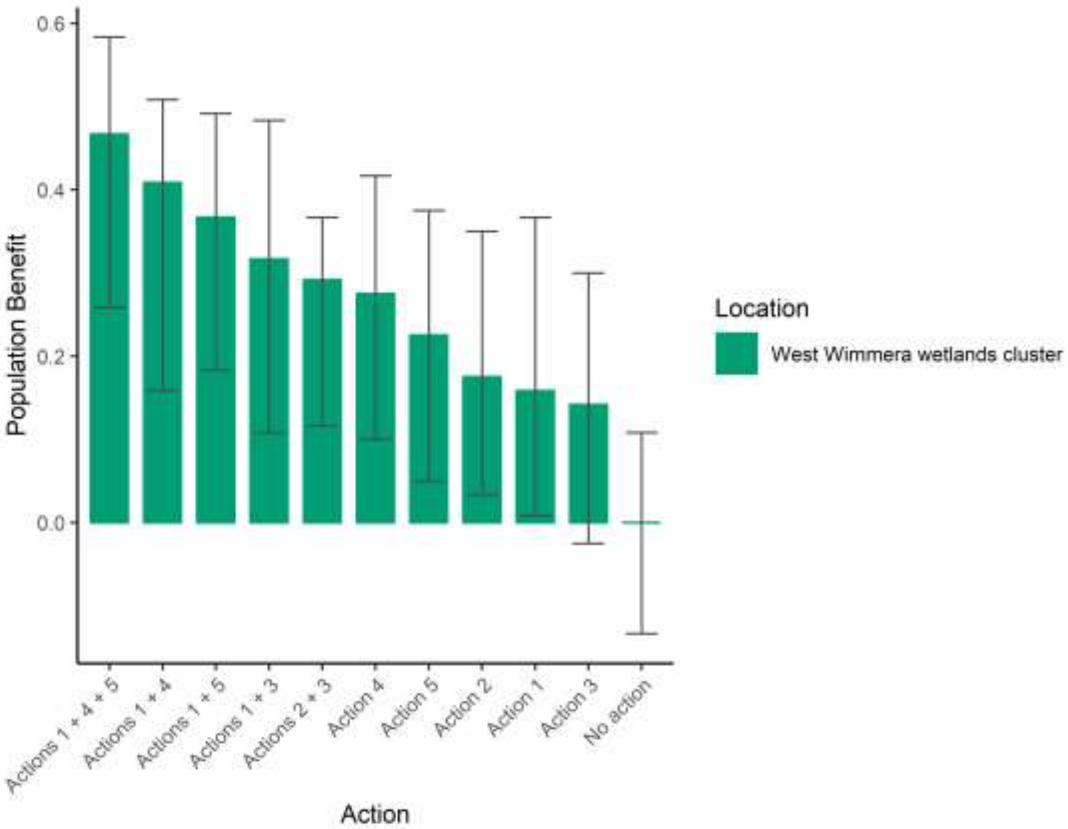

Figure 105. Mean change in *Nitella* sp. aff. *cristata* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

This species demonstrates a high potential benefit from a combination of actions; however, single actions show a clear and progressive benefit rank. The highest ranked independent action is the exclusion of stock through fencing. The ranking of actions reflects the sensitivity of this wetland species to each threat.

Species: Desmids of alpine bogs (diverse and unique algal community)

Number of experts: 3

Locations:

Baw Baw Alpine

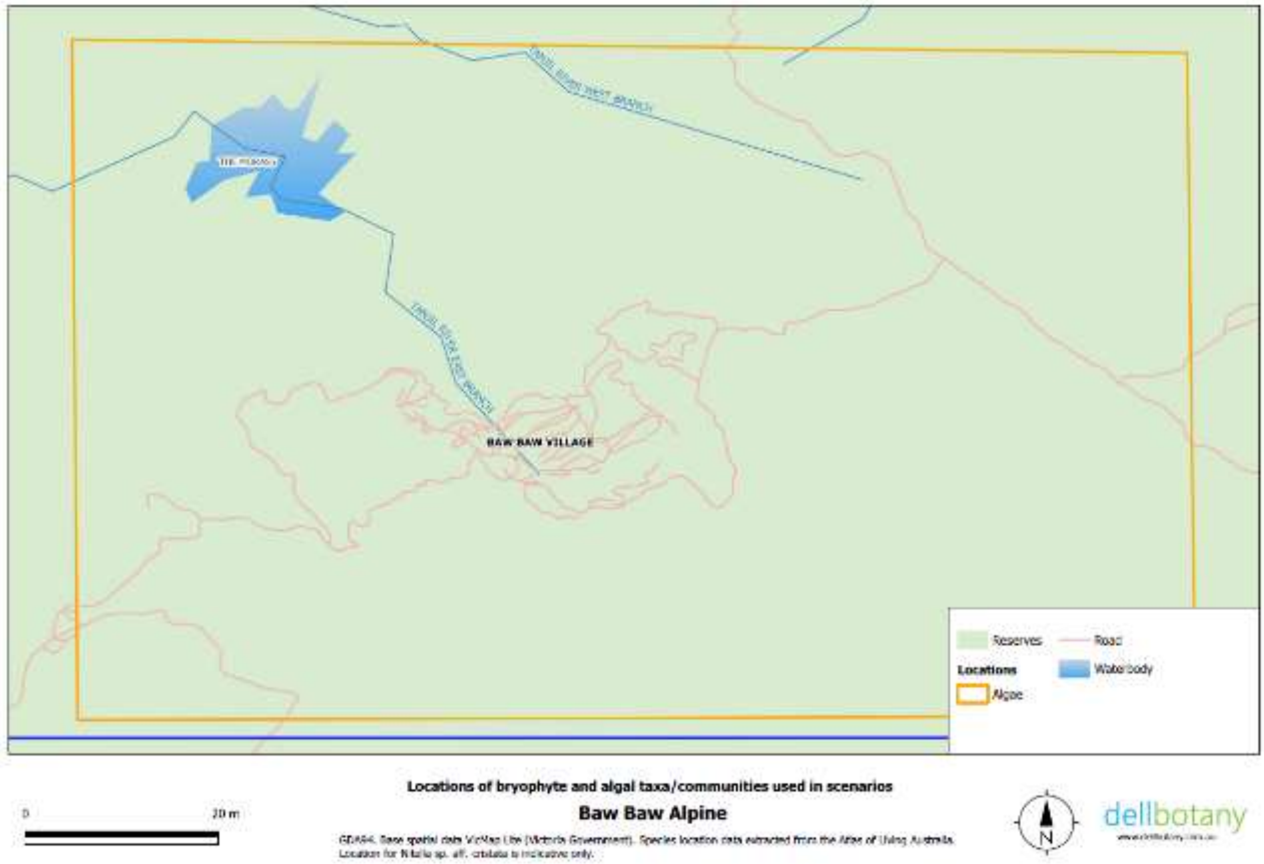

Figure 106. Locations for Desmids of alpine bogs (diverse and unique algal community) actions.

#	Actions:

	No action	As described.
1	Strategic burns to protect habitat	This action includes only the use of fuel reduction burns - the burning of vegetation at tolerable intervals, in landscape positions that are strategically important for reducing impacts to wet forest gullies. Fuel reduction burns in the Tanjil foothills to south west of populations. 50% of area burned in a mosaic over 10 years.
2	Undulate pest animal control	Reduction of pest ungulate animal density within the landscape to negligible level. This includes the removal of animals (population reduction) rather than the control of their movement or other control measure to reduce impacts. Control may include combinations of culling and or capture.
3	Collection and culture in recognised collection facilities	Since most algae are microscopic, maintenance of the genetic resource in culture, or as propagules, would be the most comprehensive way to minimise biodiversity/genetic loss for the entire group. This would entail either depositing Victorian material in a recognised culture facility (e.g. Australian National Algae Culture Collection), and supporting its retention, and/or including algae in the current seed-banking projects that exist (e.g. Australian Seed Bank Partnership). This *ex situ* action is undertaken to enable future re-introduction of material at the location, for ecological management purposes.
4	Exclosure fencing	Exclosure fencing is a contiguous barrier that prevents target pest animals from accessing defined areas. It is assumed for this purpose that an exclosure is 100% effective at preventing access for the target pest animal (deer). Fences typically comprise 2 m tall post and wire mesh barriers. For this exercise, five alpine peatland/bog sites of 2 ha each would be fenced to exclude ungulate pest animals. Sites are spread widely across Baw Baw Alps.

Based on expert assessment the benefit of each action at each location for these species is as follows:

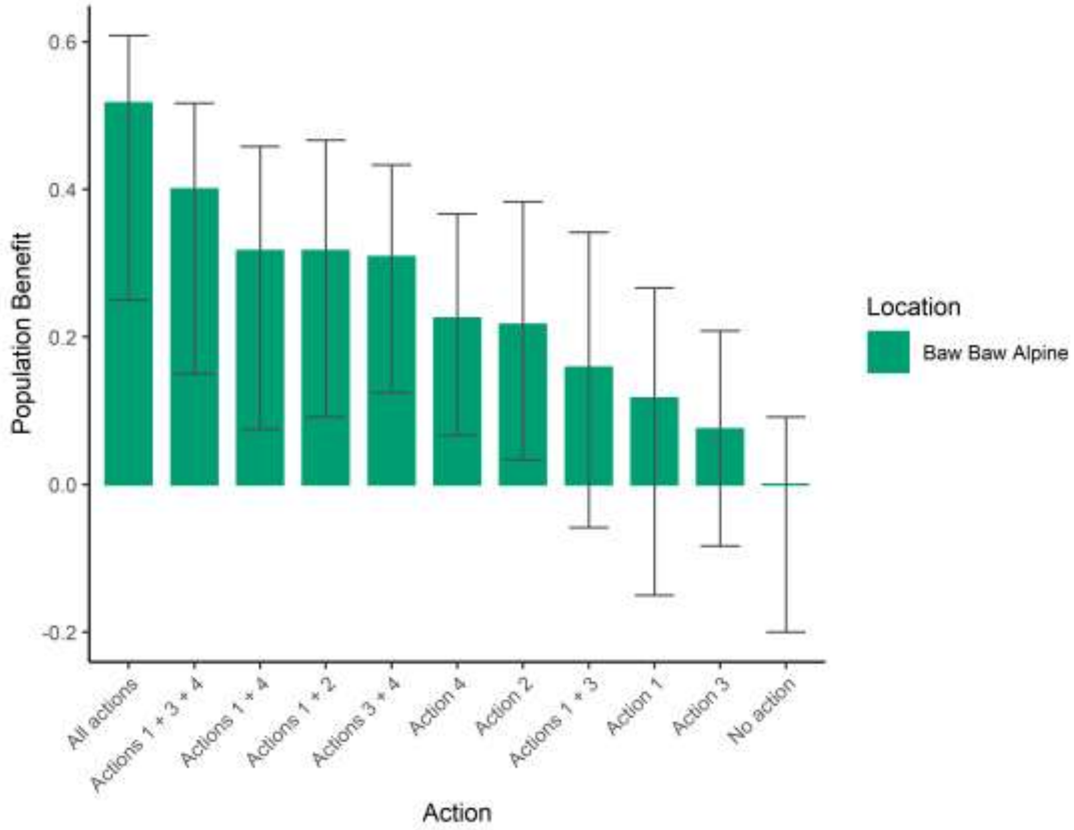

Figure 107. Mean change in desmids of alpine bogs probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

For this group of species, as with others, a combination of actions is preferred. However strategic burns to protect habitat and undulate pest animal control are likely the most beneficial options, as determined by their individual benefit estimates.

Critical-weight-range mammals and macropods

Introduction

Five species were selected for this analysis. This taxon has been largely assessed through the prism of fires. Each has been greatly impacted by the 2019/20 bushfires and as a result has been recommended for bespoke action to aid recovery, promote resilience, and ensure future persistence.

Key knowledge gaps

I. Effect of high intensity fire on critical weight range mammal density

This model explores the impacts of high intensity fire on critical weight range (CWR) mammal density. The system considers vegetation cover, as well as density of major predators, competitors, and food sources as key determinants.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

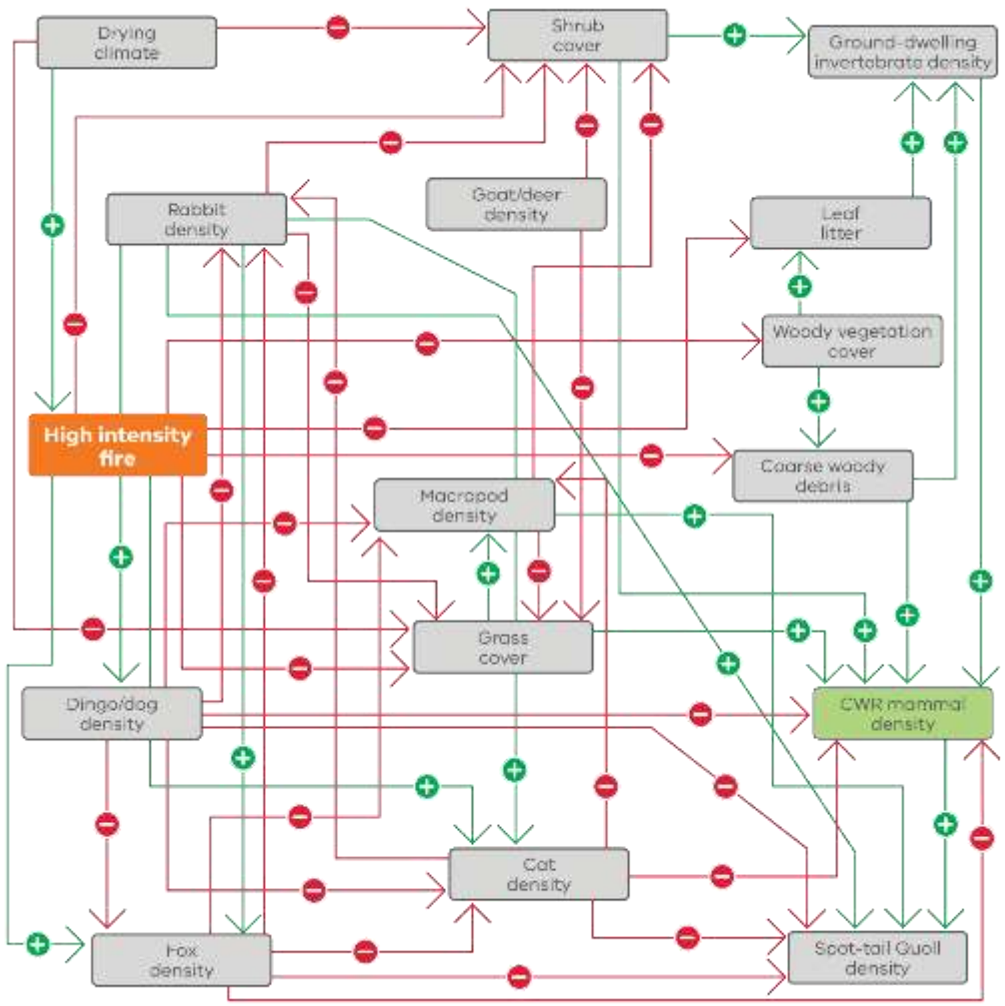

Figure 108. Best case scenario casual model for effect of high intensity fire on CWR mammal density. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

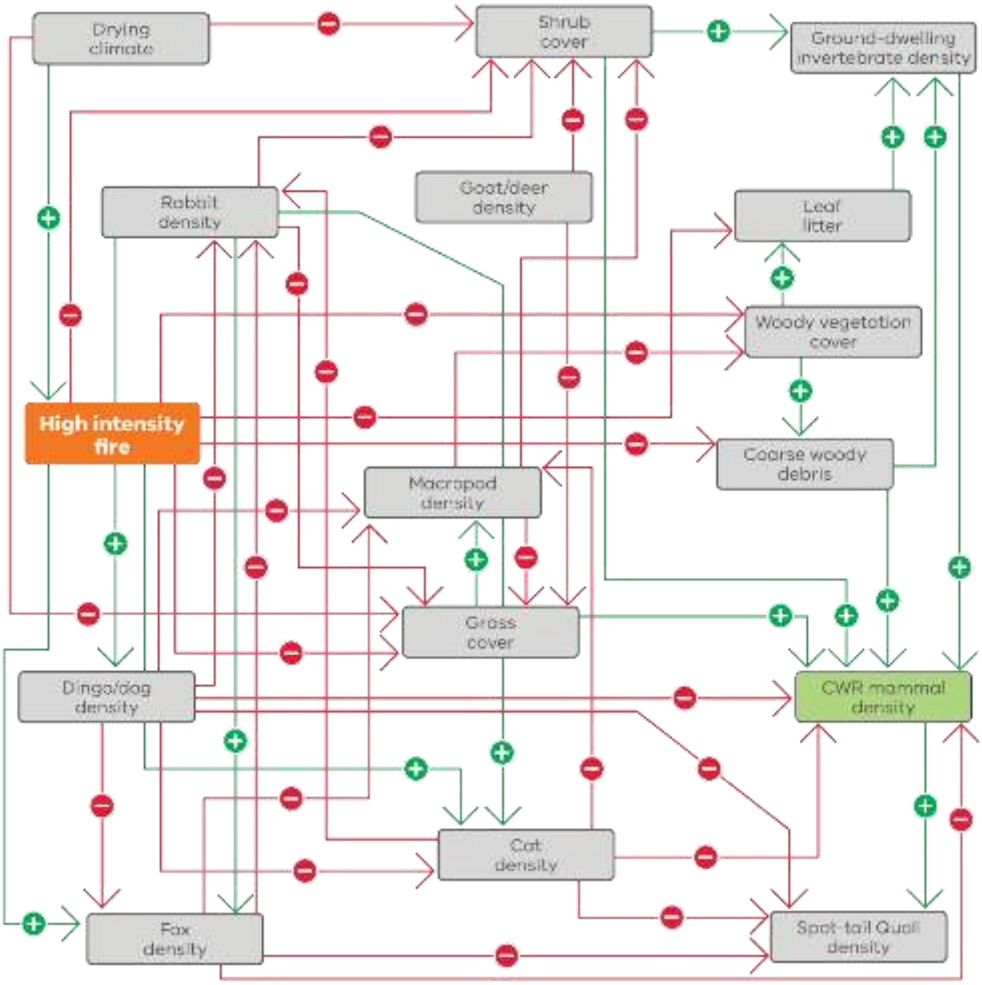

Figure 109. Worst case scenario casual model for effect of high intensity fire on CWR mammal density. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Macropod density	Spot tail Quoll density	0.049
2	Goat and deer density	Shrub cover	0.024
2	Shrub cover	CWR mammal density	0.024
2	Shrub cover	Ground dwelling invertebrate density	0.024
2	Drying climate	Shrub cover	0.024
2	Drying climate	Grass cover	0.024
2	Drying climate	High intensity fire	0.024
2	CWR mammal density	Spot tail Quoll density	0.024
2	Ground dwelling invertebrate density	CWR mammal density	0.024
2	Rabbit density	Shrub cover	0.024
2	Rabbit density	Spot tail Quoll density	0.024
2	Rabbit density	Cat density	0.024
2	Rabbit density	Fox density	0.024
2	Rabbit density	Dingo dog density	0.024
2	Grass cover	CWR mammal density	0.024
2	Grass cover	Macropod density	0.024
2	Coarse woody debris	CWR mammal density	0.024
2	Coarse woody debris	Ground dwelling invertebrate density	0.024
2	High intensity fire	Shrub cover	0.024
2	High intensity fire	Grass cover	0.024
2	High intensity fire	Woody vegetation cover	0.024
2	High intensity fire	Coarse woody debris	0.024
2	High intensity fire	Cat density	0.024
2	High intensity fire	Fox density	0.024
2	Leaf litter	Ground dwelling invertebrate density	0.024
2	Macropod density	Shrub cover	0.024
2	Macropod density	Grass cover	0.024
2	Macropod density	Woody vegetation cover	0.024
2	Cat density	Rabbit density	0.024
2	Cat density	Macropod density	0.024
2	Cat density	Spot tail Quoll density	0.024
2	Fox density	Rabbit density	0.024
2	Fox density	Macropod density	0.024
2	Fox density	Spot tail Quoll density	0.024
2	Fox density	Cat density	0.024
2	Dingo dog density	Rabbit density	0.024
2	Dingo dog density	Macropod density	0.024
2	Dingo dog density	Spot tail Quoll density	0.024
2	Dingo dog density	Cat density	0.024
2	Dingo dog density	Fox density	0.024

Figure 110. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for high intensity fire on CWR mammal density.

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The highest ranked link was macropod density on Spot-Tailed Quoll density, making this a good potential candidate for a research project, as it represents the highest reduction in uncertainty of 0.049. All other links appear to be equal candidates for research projects, as they each represent an equivalent reduction in uncertainty of 0.024.

II. Effect of low intensity fire on CWR mammal density

This model explores the impacts of low intensity fire on CWR mammal density. The system considers vegetation cover, as well as density of major predators, competitors, and food sources as key determinants. Contrasting with the previous model allows for a distinction in effect of fire depending on intensity.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

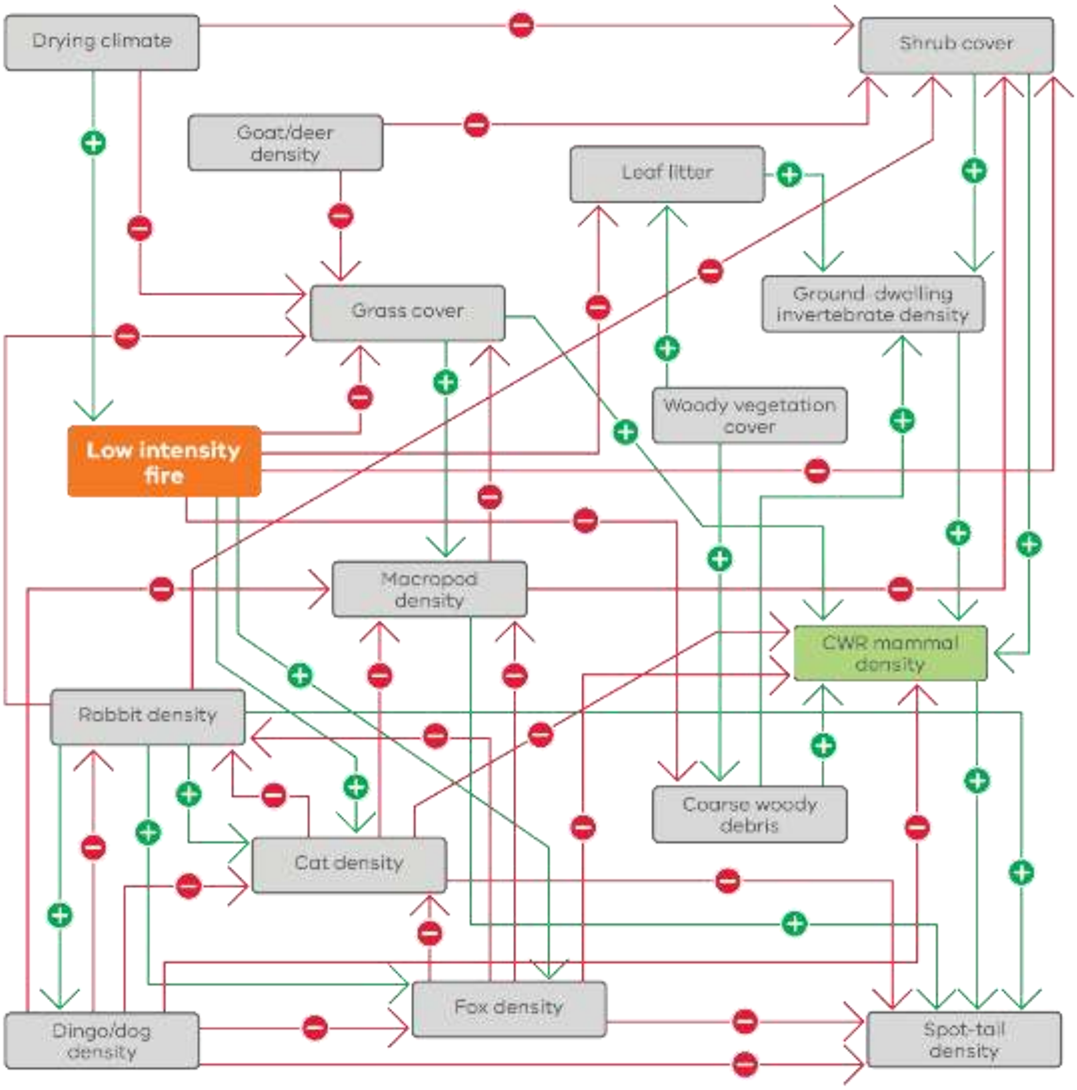

Figure 111. Best case scenario casual model for effect of low intensity fire on CWR mammal density. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

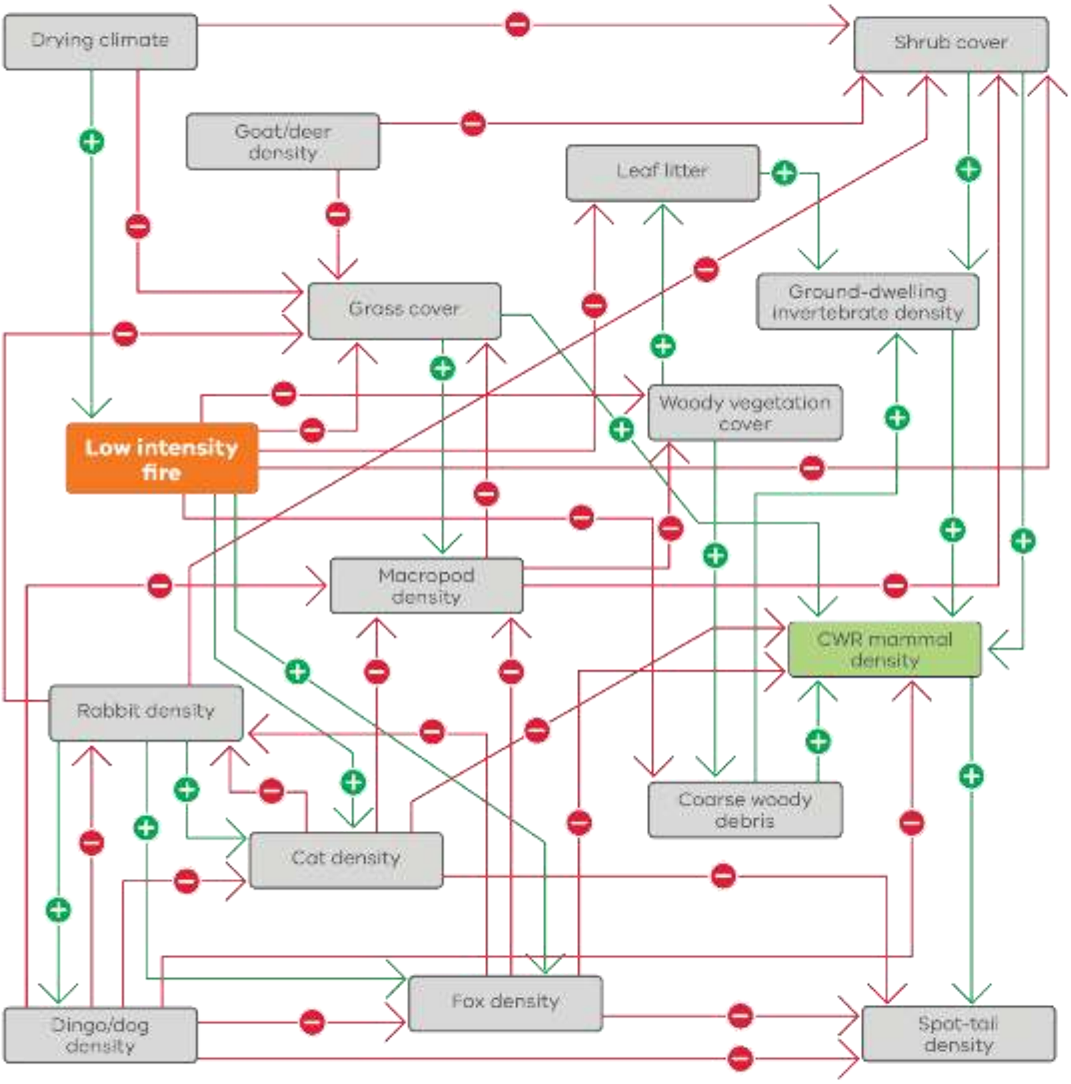

Figure 112. Worst case scenario casual model for effect of high intensity fire on CWR mammal density. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Low intensity fire	Shrub cover	0.047
1	Macropod density	Spot tail Quoll density	0.047
3	Goat and deer density	Shrub cover	0.023
3	Shrub cover	CWR mammal density	0.023
3	Shrub cover	Ground dwelling invertebrate density	0.023
3	Drying climate	Shrub cover	0.023
3	Drying climate	Grass cover	0.023
3	Drying climate	Low intensity fire	0.023
3	CWR mammal density	Spot tail Quoll density	0.023
3	Ground dwelling invertebrate density	CWR mammal density	0.023
3	Rabbit density	Shrub cover	0.023
3	Rabbit density	Spot tail Quoll density	0.023
3	Rabbit density	Cat density	0.023
3	Rabbit density	Fox density	0.023
3	Rabbit density	Dingo dog density	0.023
3	Grass cover	CWR mammal density	0.023
3	Grass cover	Macropod density	0.023
3	Coarse woody debris	CWR mammal density	0.023
3	Coarse woody debris	Ground dwelling invertebrate density	0.023
3	Low intensity fire	Grass cover	0.023
3	Low intensity fire	Woody vegetation cover	0.023
3	Low intensity fire	Coarse woody debris	0.023
3	Low intensity fire	Leaf litter	0.023
3	Low intensity fire	Cat density	0.023
3	Low intensity fire	Fox density	0.023
3	Leaf litter	Ground dwelling invertebrate density	0.023
3	Macropod density	Shrub cover	0.023
3	Macropod density	Grass cover	0.023
3	Macropod density	Woody vegetation cover	0.023
3	Cat density	Rabbit density	0.023
3	Cat density	Macropod density	0.023
3	Cat density	Spot tail Quoll density	0.023
3	Fox density	Rabbit density	0.023
3	Fox density	Macropod density	0.023
3	Fox density	Spot tail Quoll density	0.023
3	Fox density	Cat density	0.023
3	Dingo dog density	Rabbit density	0.023
3	Dingo dog density	Macropod density	0.023
3	Dingo dog density	Spot tail Quoll density	0.023
3	Dingo dog density	Cat density	0.023
3	Dingo dog density	Fox density	0.023

Figure 113. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for low intensity fire on CWR mammal density.

The highest ranked links were low intensity fire on shrub cover and macropod density on Spot-Tailed Quoll density, which might be a good candidate for a research project, as it represents the highest reduction in uncertainty of 0.049. All other links appear to be equal candidates for research projects, as they each represent an equivalent reduction in uncertainty of 0.024.

Priority medium term actions for conservation

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 115 and 116) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Long-Footed Potoroo (*Potorous longipes*)

Number of experts: 7

Locations:

Barry Mountains, East Gippsland.

Current population in Victoria: Barry Mountains and East Gippsland are the only two areas of occurrence for Long-footed Potoroo.

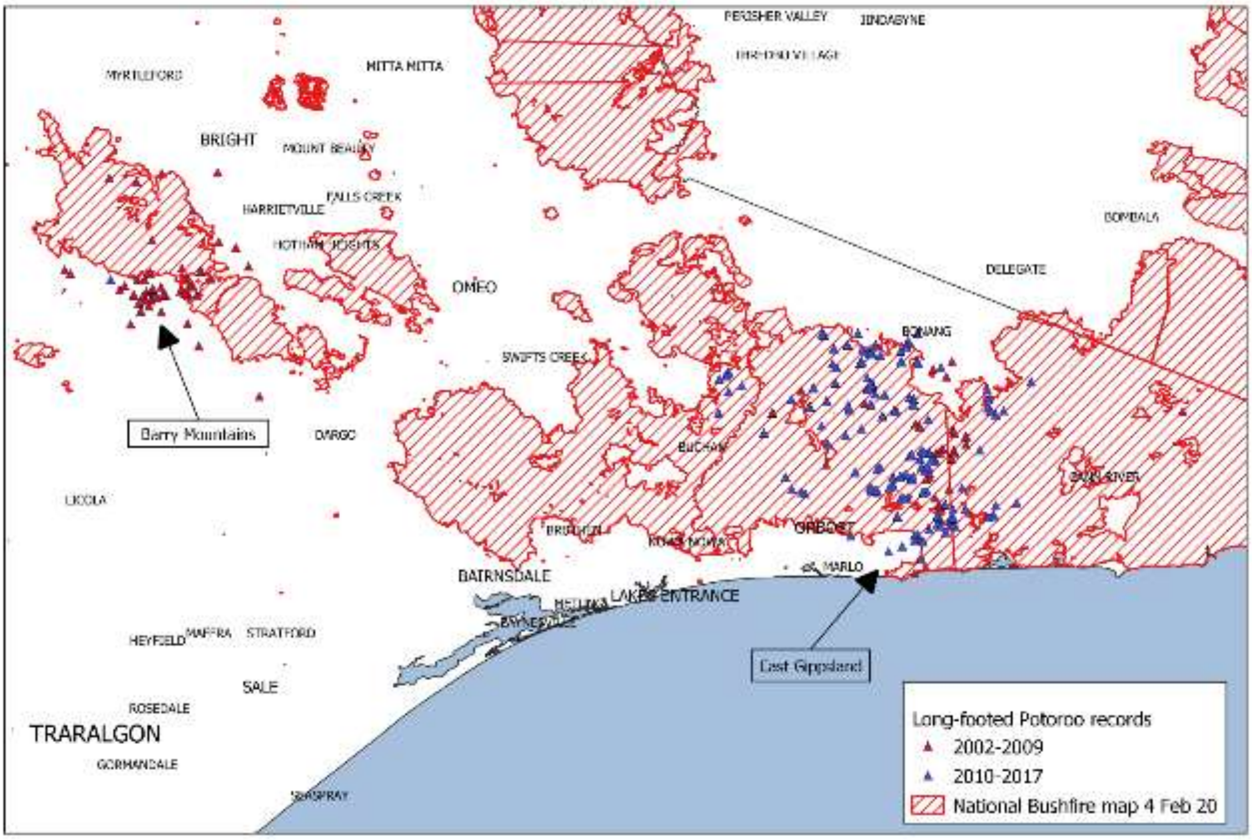

Figure 114. Locations for Long-Footed Potoroo actions.

#	Actions:	
	No action	Does not refer to no management actions taking place, instead refers to a scenario where no direct management is being undertaken for the species. More common and already-established means of land management (e.g. predator and weed control, planned burns, etc.) are assumed to be ongoing.
1	Translocation from East Gippsland	Capture of individuals from original location and release to action location. Number of individuals per translocation event will be 10-15, and two translocation events will take place in each year, over two years. Included in this action is regular monitoring of the population at the release site, which may result in fewer translocation events if the population is sufficiently stable. The specific area of release is a hypothetical location with known presence of the species prior to translocation, to allow for gene mixing.
2	Wild release from captivity	As with translocation, 10-20 individuals will be released in the action location from captive stock. In order to have sufficient numbers and adequate genetic diversity for release, a captive breeding population would be established, and the actual release event would take place once release criteria have been met. For the release action specifically, two release events per year for two years are proposed, including monitoring of release site populations. As with translocation, the area of release will have an already-established population of the species.
3	Translocation from Barry Mountains	Capture of individuals from original location and release to action location. Number of individuals per translocation event will be 10-15, and two translocation events will take place in each year, over two years. Included in this action is regular monitoring of the population at the release site, which may result in fewer translocation events if the population is sufficiently stable. The specific area of release is a hypothetical location with known presence of the species prior to translocation, to allow for gene mixing.

Based on expert assessment the benefit of each action at each location for this species is as follows:

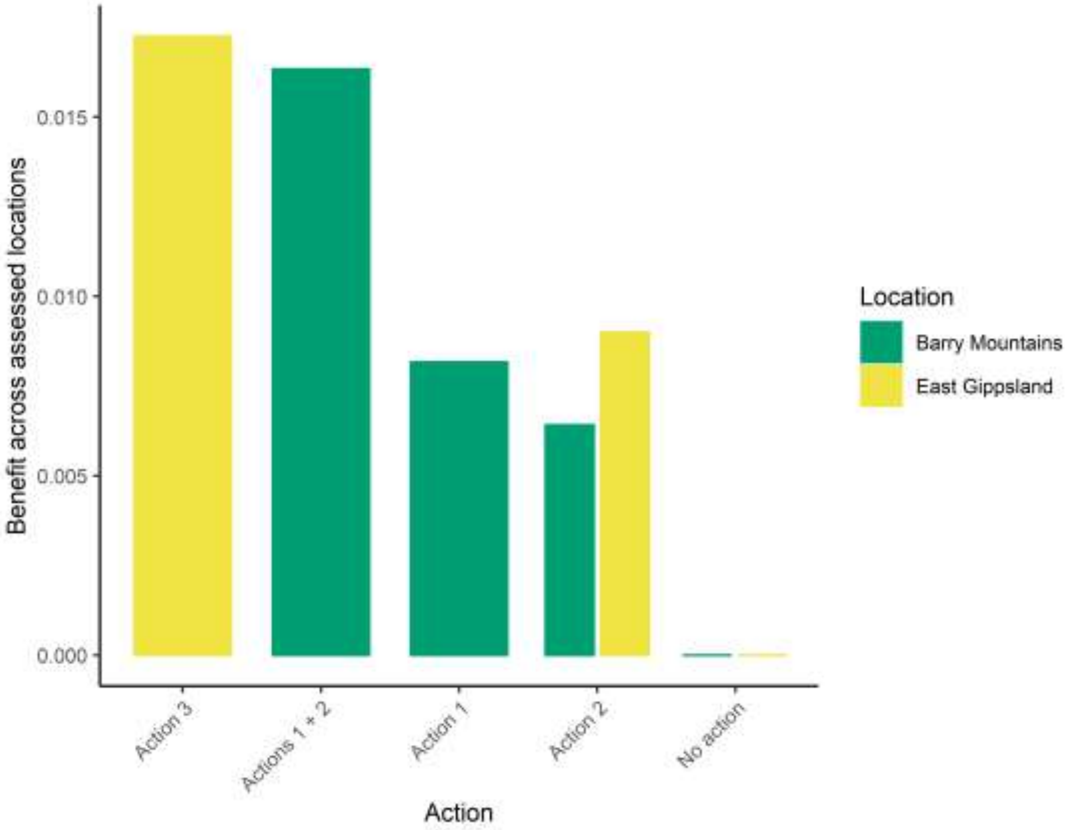

Figure 115. Benefit of each action/location combination to the Long-Footed Potoroo overall persistence probability across all assessed locations.

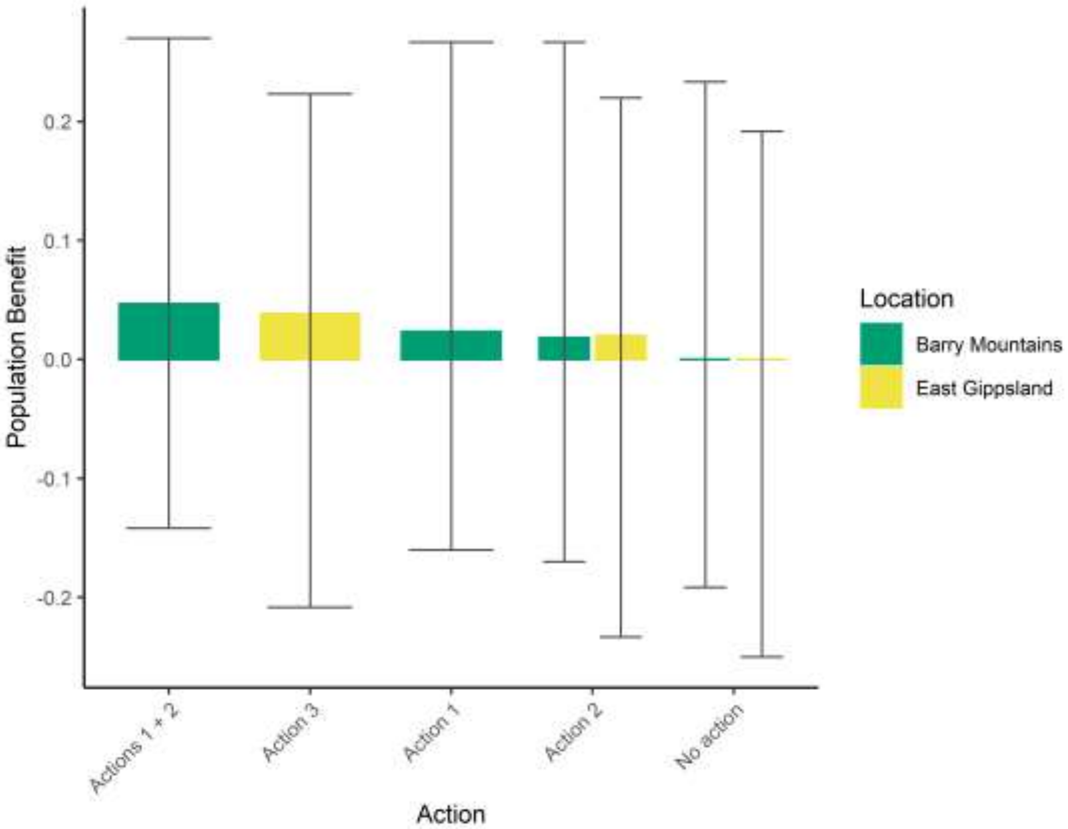

Figure 116. Mean change in Long-Footed Potoroo probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Benefits of the proposed actions for these species were not rated relatively highly (<0.1) by experts. There was also a large variability between the upper and lower estimates, indicating that impacts of translocation in this case are uncertain and may not reliably improve probability of persistence for Long-Footed Potoroos.

Species: Long-Nosed Potoroo (*Potorous tridactylus*)

Number of experts: 7

Locations:

French Island, Grampians National Park, Otways, Wilson's Promontory.

Current population in Victoria: All areas of occurrence for Long-nosed Potoroo were chosen for actions with the exception of East Gippsland, owing to the high density of occurrence records from the area.

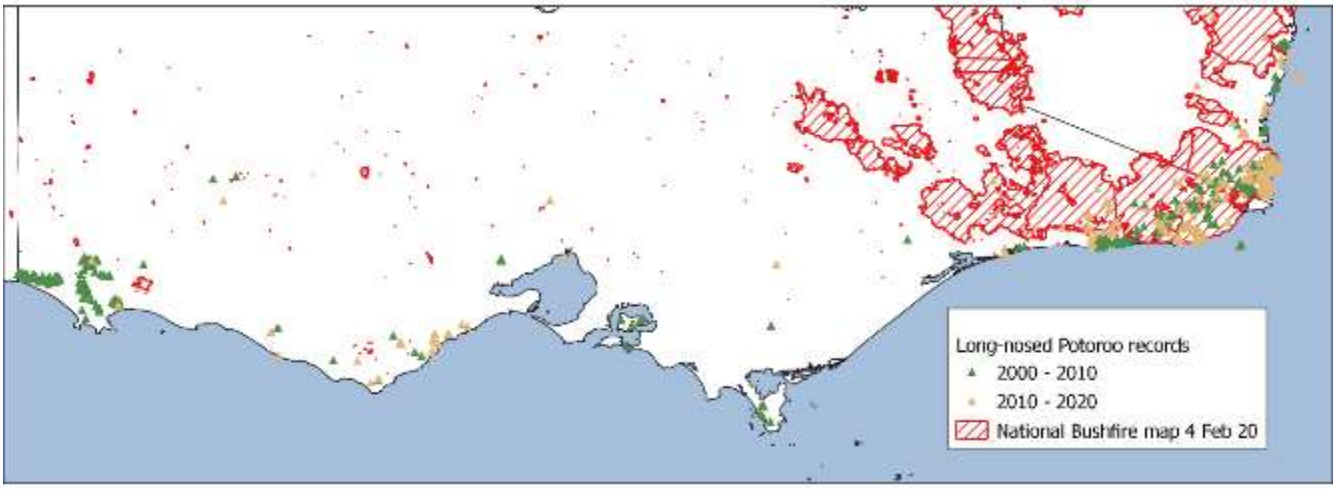

Figure 117. Locations for Long-Nosed Potoroo actions.

#	Actions:	
	No action	Does not refer to no management actions taking place, instead refers to a scenario where no direct management is being undertaken for the species. More common and already-established means of land management (e.g. predator and weed control, planned burns, etc.) are assumed to be ongoing.
 1 2 3	Translocation from Barwon South West from East Gippland from Otways	Capture of individuals from original location and release to action location. Number of individuals per translocation event will be 10-20, and two translocation events will take place in each year, over two years. Included in this action is regular monitoring of the population at the release site, which may result in fewer translocation events if the population is sufficiently stable. The specific area of release is a hypothetical location with known presence of the species prior to translocation, to allow for gene mixing.
4	Wild release from captivity	As with translocation, 10-20 individuals will be released in the action location from captive stock. In order to have sufficient numbers and adequate genetic diversity for release, a captive breeding population would be established, and the actual release event would take place once release criteria have been met. For the release action specifically, two release events per year for two years are proposed, including monitoring of release site populations. As with translocation, the area of release will have an already-established population of the species.

Based on expert assessment the benefit of each action at each location for this species is as follows:

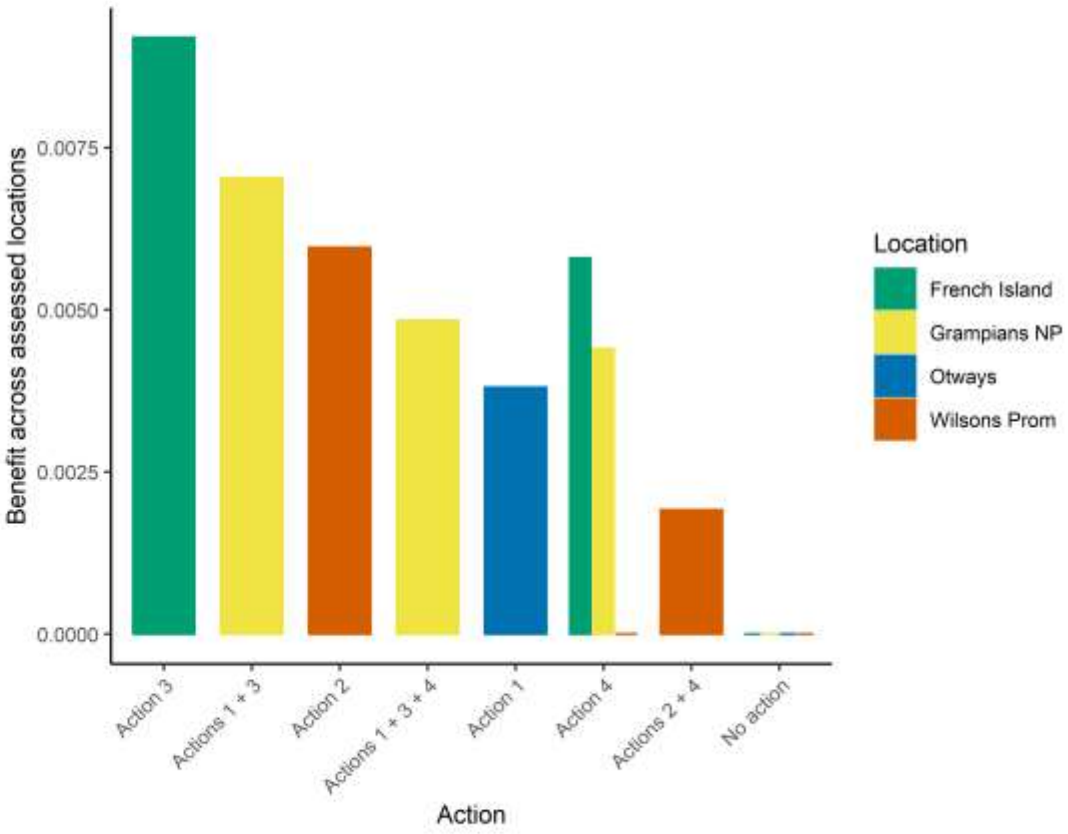

Figure 118. Benefit of each action/location combination to the Long-Nosed Potoroo overall persistence probability across all assessed locations.

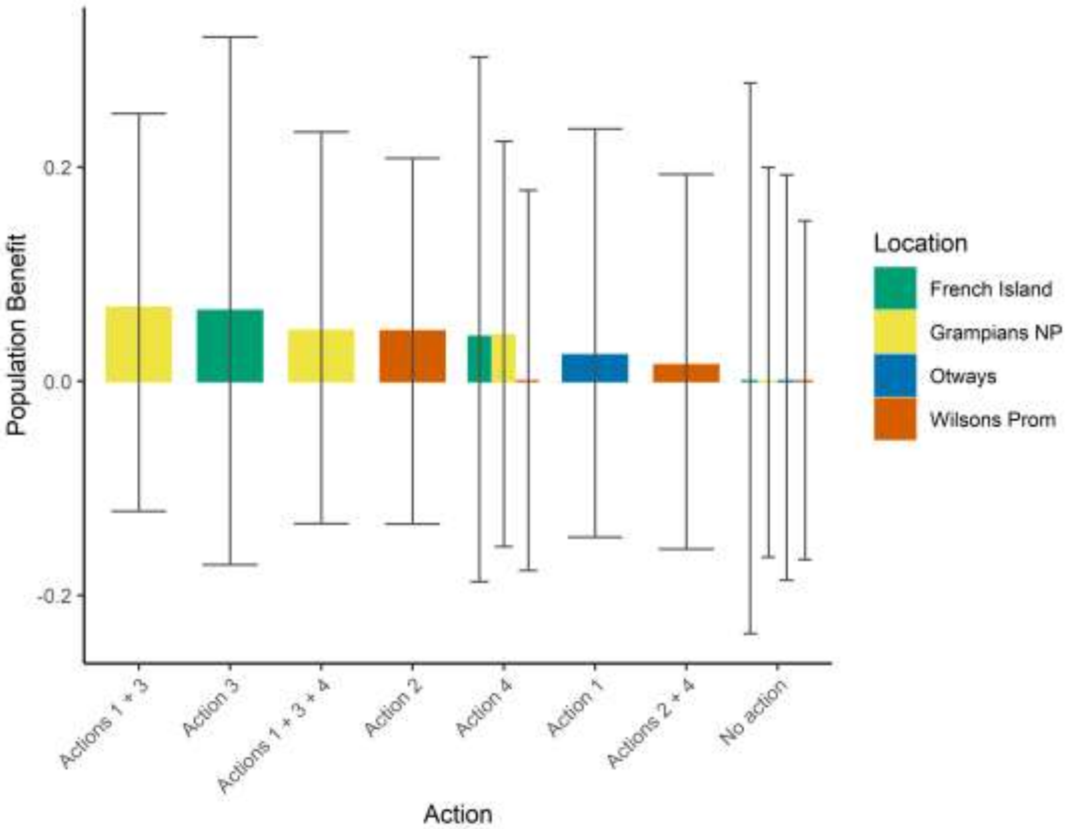

Figure 119. Mean change in Long-Nosed Potoroo probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

These results compare the relative benefit for translocation actions sourcing from 3 regions and releasing into existing population, facilitating gene mixing, after some time of captive breeding. When assessing the benefit at each location, there does not appear to be great variation between appropriate actions at each site, and there is some variation between the plausible upper and lower estimates. Across all locations, releasing individuals sourced from Wilson's Prom onto French Island is rated as most beneficial to the probability of persistence of Long-Nosed Potoroos.

Species: Southern Brown Bandicoot (*Isoodon obesulus)*

Number of experts: 7

Locations:

East Gippsland, Grampians National Park, Port Campbell, Wilson's Promontory.

Current population in Victoria: Action locations were chosen based on the relatively fewer number of occurrences compared to hotspots (e.g. Westernport, Barwon South West). East Gippsland was included due to presumed reduction in habitat from 2019/20 fires.

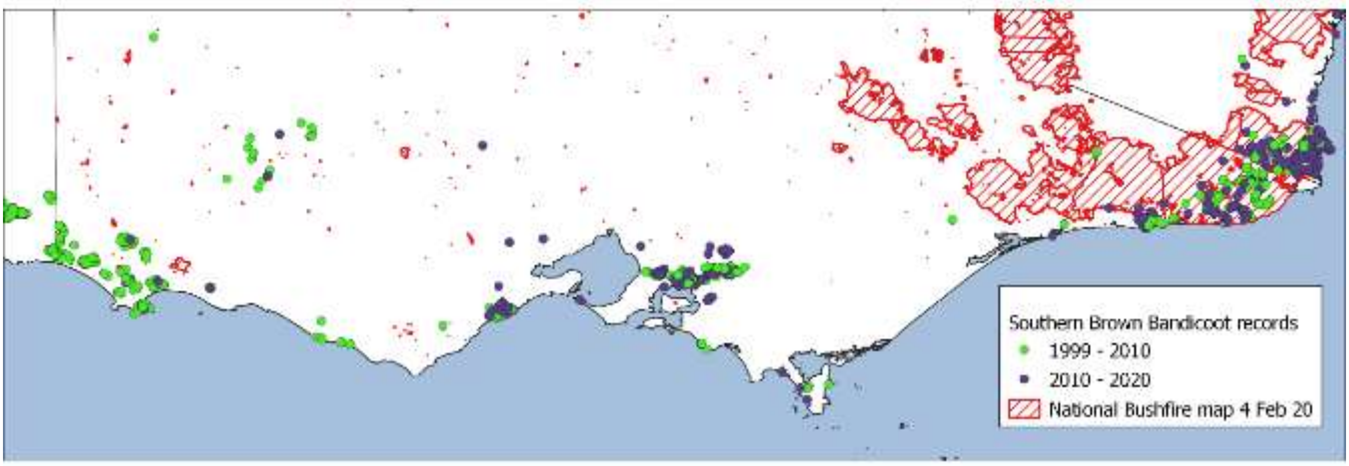

Figure 120. Locations for Southern Brown Bandicoot actions.

#	Actions:	
	No action	Does not refer to no management actions taking place, instead refers to a scenario where no direct management is being undertaken for the species. More common and already-established means of land management (e.g. predator and weed control, planned burns, etc.) are assumed to be ongoing.
1	Predator-free fenced reserve	Creation of a fenced area with complete eradication of foxes and cats inside, regularly patrolled for breaches. The size of the hypothetical reserve is ~300ha in either Port Campbell or Wilson's Prom. The reserve would be created in an area with known presence of bandicoots.
 2 3	Translocation from Anglesea/Barwon South West from Cranbourne/Westernport	Capture of individuals from original location and release to action location. Number of individuals per translocation event will be 10-20, and two translocation events will take place in each year, over two years. Included in this action is regular monitoring of the population at the release site, which may result in fewer translocation events if the population is sufficiently stable. The specific area of release is a hypothetical location with known presence of the species prior to translocation, to allow for gene mixing. If this is undertaken in conjunction with the creation of a predator-free reserve, then translocation will take place within the reserve.

Based on expert assessment the benefit of each action at each location for this species is as follows:

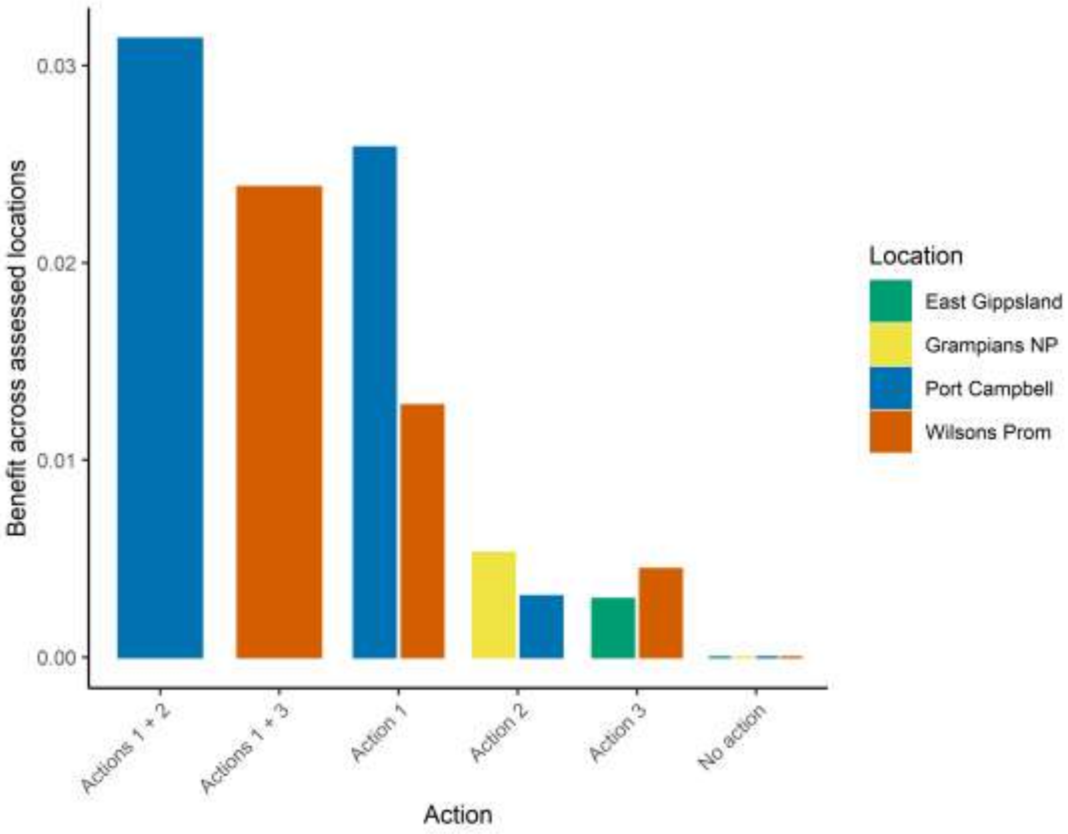

Figure 121. Benefit of each action/location combination to the Southern Brown Bandicoot overall persistence probability across all assessed locations.

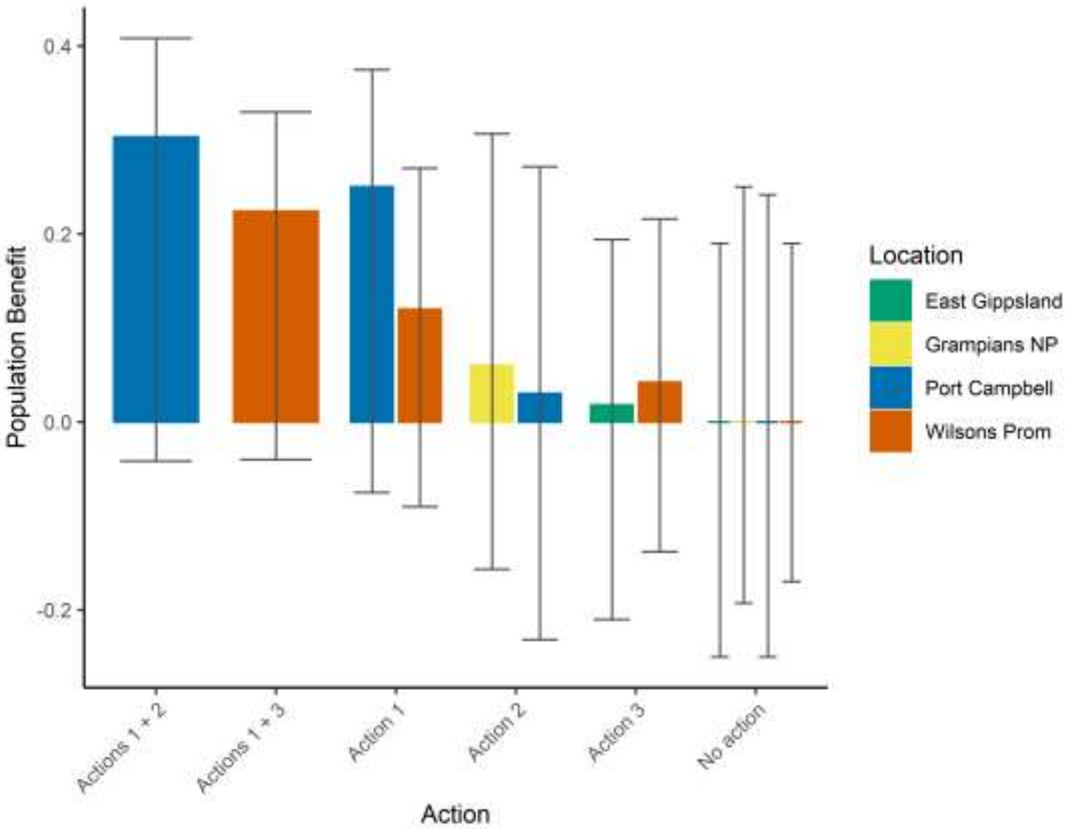

Figure 122. Mean change in Southern Brown Bandicoot probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

As with the other CWR mammal and macropod species in this assessment, the estimated benefit of proposed actions for Southern Brown Bandicoots is not high across all locations (<0.01). However, this species demonstrates higher local benefits, particularly in Port Campbell and Wilson's Prom, when receiving translocated individuals and supported by fenced predator-free conditions. Small benefit estimates for long-term persistence across the landscape likely reflect the scale of actions.

Species: Southern Long-Nosed Bandicoot (*Perameles nasuta*)

Number of experts: 7

Locations:

East Gippsland, Mornington Peninsula, Otways, Wilson's Promontory.

Current population in Victoria: Action locations were chosen based on the relatively fewer number of occurrences compared to hotspots (e.g. Central Highlands). East Gippsland was included due to presumed reduction in habitat from 2019/20 fires.

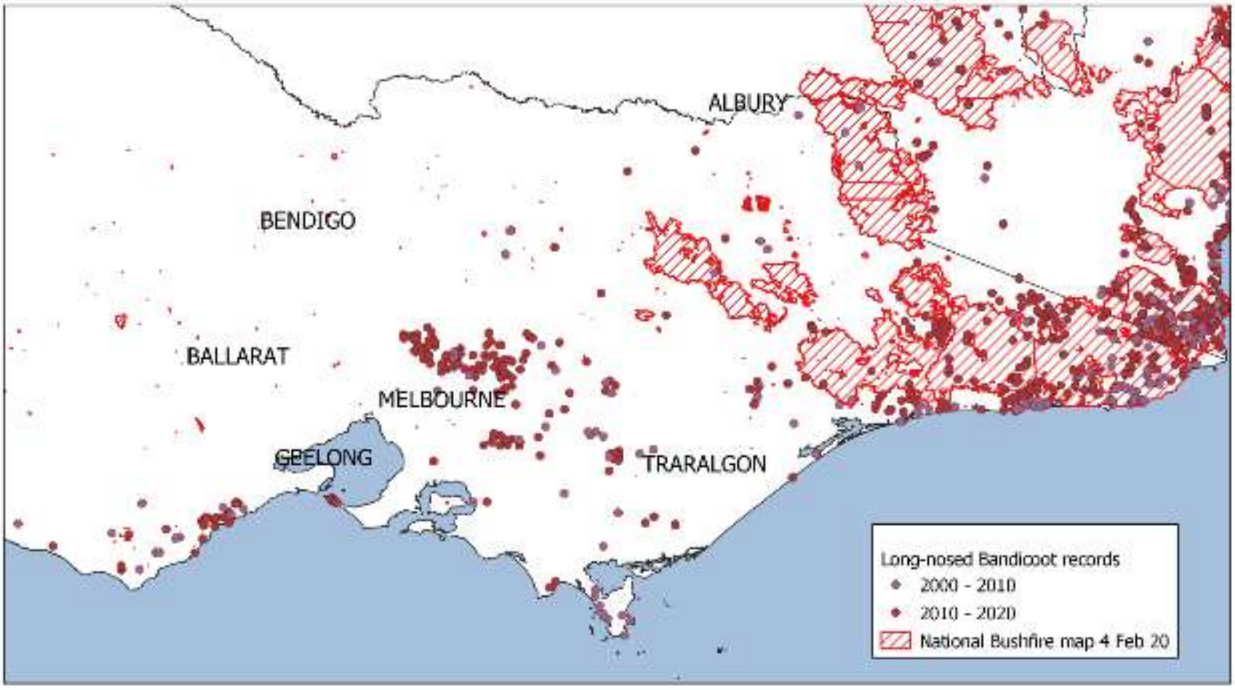

Figure 123. Locations for Southern Long-Nosed Bandicoot actions.

#	Actions:	
	No action	Does not refer to no management actions taking place, instead refers to a scenario where no direct management is being undertaken for the species. More common and already-established means of land management (e.g. predator and weed control, planned burns, etc.) are assumed to be ongoing.
 1 2 3	Translocation from Central Highlands/Mornington Peninsula from Latrobe Valley/Central Highlands from Otways/Central Highlands	Capture of individuals from original location and release to action location. Number of individuals per translocation event will be 10-20, and two translocation events will take place in each year, over two years. Included in this action is regular monitoring of the population at the release site, which may result in fewer translocation events if the population is sufficiently stable. The specific area of release is a hypothetical location with known presence of the species prior to translocation, to allow for gene mixing.

Based on expert assessment the benefit of each action at each location for this species is as follows:

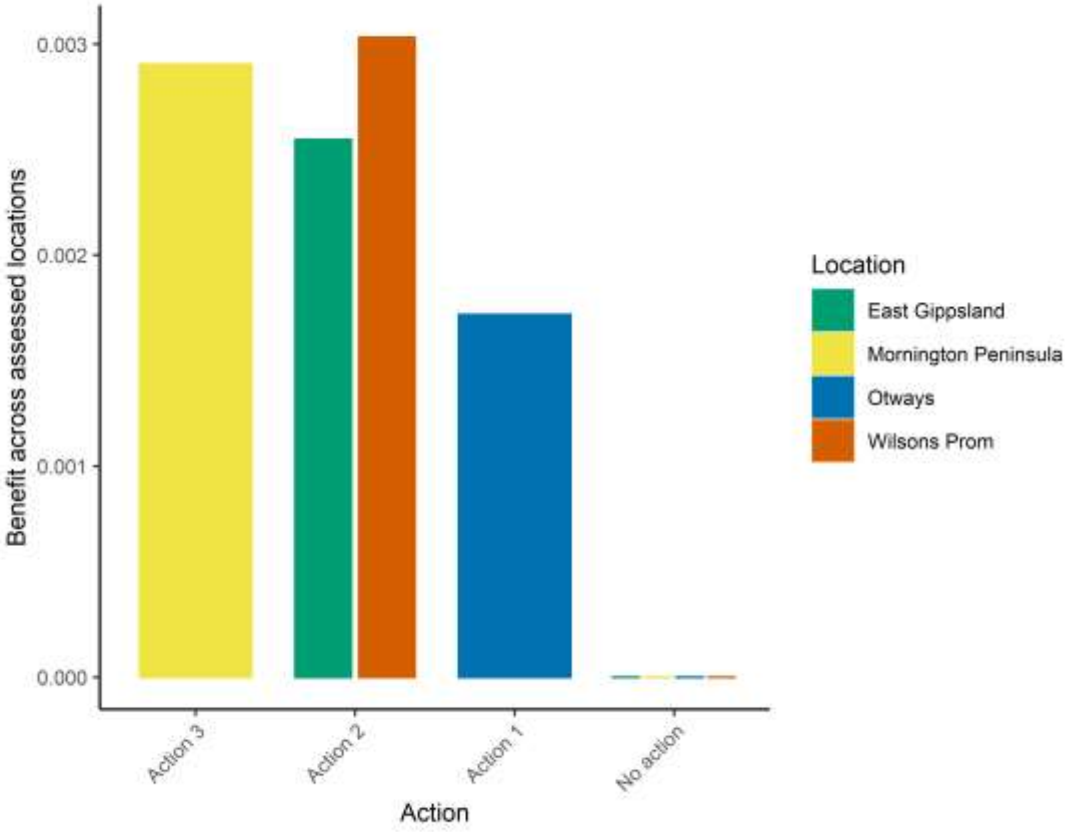

Figure 124. Benefit of each action/location combination to the Southern Long-Nosed Bandicoot overall persistence probability across all assessed locations.

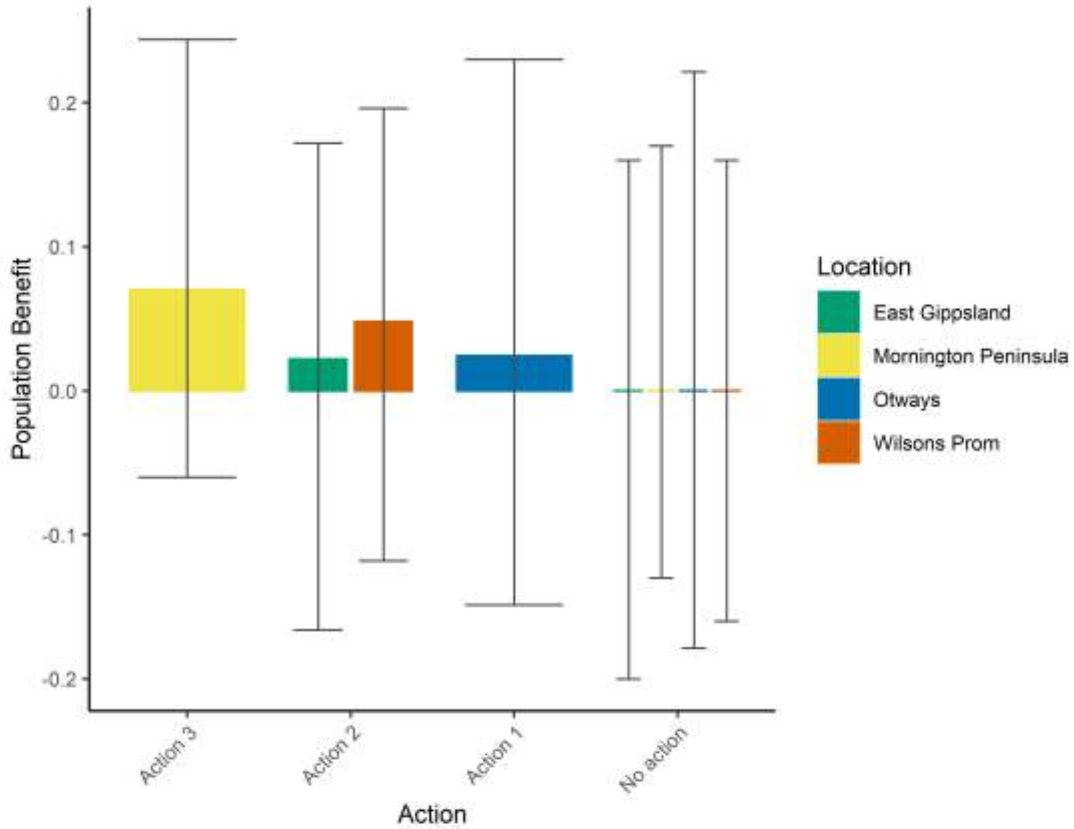

Figure 125. Mean change in Southern Long-Nosed Bandicoot probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

The estimated benefit of proposed actions for Southern Long-Nosed Bandicoots is not high, particularly across all locations (<0.005). Of the translocation actions proposed, greater success may come by sourcing from Latrobe Valley/Central Highlands and releasing in Wilson's Prom or from Otways/Central Highlands to the Mornington Peninsula. Small benefit estimates for long-term persistence across the landscape likely reflect the scale of actions.

Species: Spotted-Tailed Quoll (*Dasyurus maculatus*)

Number of experts: 7

Locations:

East Gippsland, Otways, Barwon South West, Central Highlands.

Current population in Victoria: Action locations were chosen based on areas with few recent occurrence records.

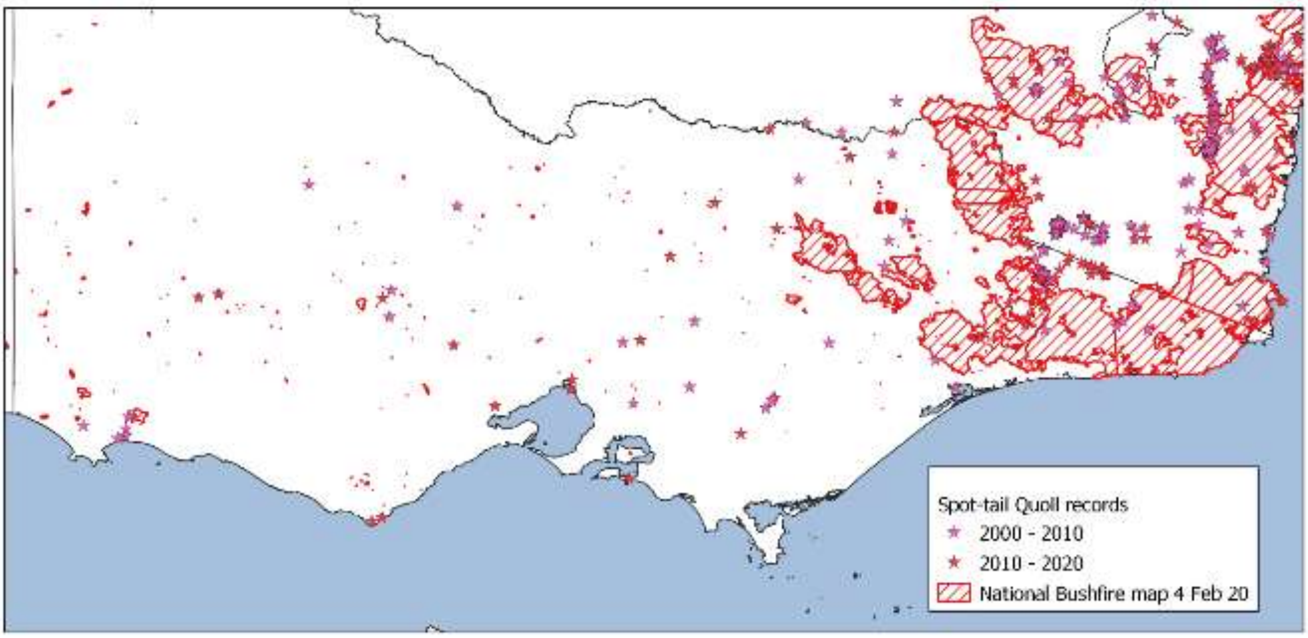

Figure 126. Locations for Spotted-Tailed Quoll actions.

	Actions:	
	No action	Does not refer to no management actions taking place, instead refers to a scenario where no direct management is being undertaken for the species. More common and already-established means of land management (e.g. predator and weed control, planned burns, etc.) are assumed to be ongoing.
1	Wild release from captivity	Release of 5-10 individuals from captive stock in the action location, with two translocation events taking place each year for two years. In order to have sufficient numbers and adequate genetic diversity for release, a captive breeding population would be established, and the actual release event would take place once release criteria have been met. The specific area of release will have an already-established population of the species (where possible, in areas with no or few records from the last ten years, the area of release will be surveyed and assessed for suitability, i.e. lack of feral predators, available habitat and prey).
2	Translocation from NSW	Single release of at least 8 individuals (5 females, 3 males) from original location to action location. As with wild release from captivity, areas of release will be assessed for suitability or have an established population. Initial capture sites would likely be in NSW, due to the relative ease of capture and abundance compared to Victorian populations.
3	Wild release from captivity + cat control	

Based on expert assessment the benefit of each action at each location for this species is as follows:

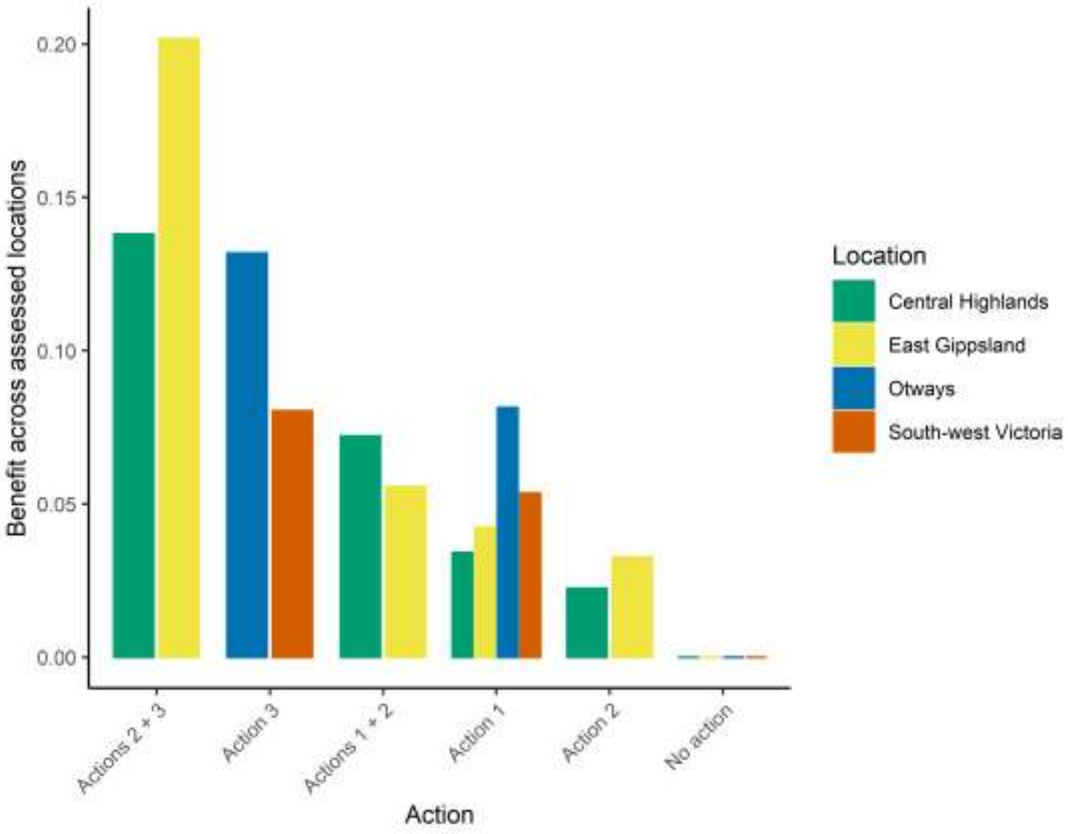

Figure 127. Benefit of each action/location combination to the Spotted-Tailed Quoll overall persistence probability across all assessed locations.

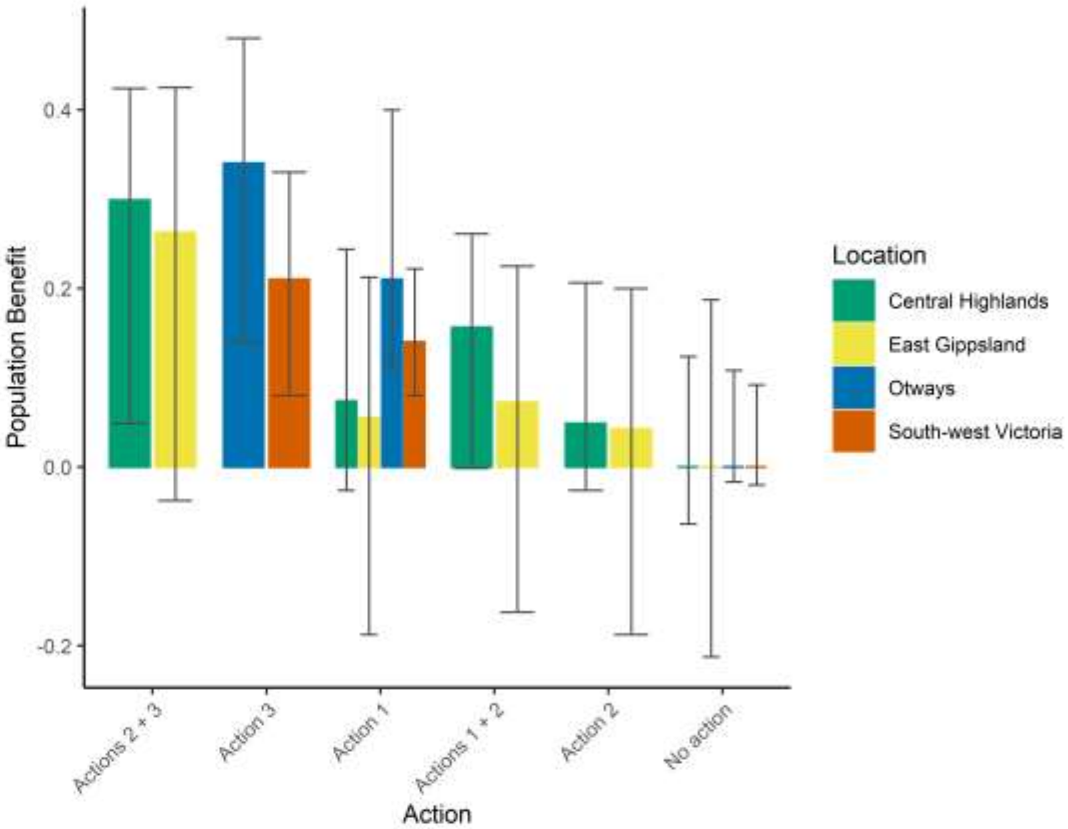

Figure 128. Mean change in Spotted-Tailed Quoll probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Similar to other CWR mammals and macropods in this assessment, actions for the Spotted-Tailed Quoll centre around translocation. However, it is proposed that this species be sourced from NSW. Additionally, major benefits are estimated to occur when release is combined with cat control. This is the case if release is wild or from captivity, highlighting cats as a major threat to population survival and long-term persistence.

Fungi

Introduction

An initial workshop was run in September 2020 to identify key species, threats and actions for fungi. Taxa chosen were representative of trophic groups (with different nutritional strategies) and morphogroups of macrofungi, occurring in some different habitats. Threats and actions were discussed for:

- Epigean ectomycorrhizal fungi of Cool Temperate Rainforest
- Wood-inhabiting fungi in wet forests
- Truffle-like ectomycorrhizal fungi of Eucalyptus forest and woodland
- Waxcap (Hygrophoraceae) community

Some participants commented that not all groups of fungi were covered. Other functional groups suggested as important were: (1) endophytic fungi (diverse and ubiquitous in both grassy and non-grassy plants) which have been shown to improve drought tolerance. Little is known about them beyond a simple understanding that if their plant hosts do not regenerate after fire, any fungi obligately associated with particular hosts will not persist. Also, if the fungi become less prevalent due to fire, then regenerating vegetation could be less resilient to droughts. (2) microfungi on native plants – there are highly diverse microfungi that are parasites (necrotrophs and biotrophs) of all native plants. Many of these fungi are host specific and any limited the threatened plants or plant communities will be threatened. (3) AM (arbuscular mycorrhizal) fungi are very common as mutualistic symbionts of a wide range of plants. They are less host limited than ECM fungi. (4) other types of mycorrhizal fungi such as orchid mycorrhizal fungi and ericoid mycorrhizal fungi. (5) Lichenised fungi (lichens) are diverse in Victoria, and a few species are already assessed as threatened.

Following the workshop, this information assisted development of Specific Needs assessments to capture the relative benefit of species-specific management actions. Allied to this, Causal Models were produced. The limited number of fungi experts in Victoria and lack of detailed information made the task of selecting species and conducting elicitation for Specific Needs analysis difficult.

Participants in the workshop, and mycologists contacted during the project were positive about the inclusion of fungi in the Specific Needs Assessment, despite the high degree of uncertainty in suggesting and assessing actions.

In general, because there are no specific management actions yet in place for fungi in Victoria, beyond survey, monitoring and research, most actions had to be developed from scratch. Many actions are consequently hypothetical, and if implemented, would need to be based on prior research and testing, especially for reintroduction.

See supplementary report for reference material and further information.

Key knowledge gaps

Causal models were developed for two problem-response scenarios related to broadscale landscape action or a common issue that needs exploration in more detail. The models will be used to identify key knowledge gaps and guiding future investment in research. These models do not include all factors but attempt to capture major influences on the abundance of the fungi concerned.

Below are the scenarios for each system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

I. Loss of populations of *Hypocreopsis amplectens* due to effects of climate change and habitat loss

This model describes the effects of climate change and habitat loss on the abundance of *Hypocreopsis amplectens*. Important factors are wildfire, as well as the abundance of woody substrates for the host fungus and the abundance of the host fungus, which are both related to vegetation structure.

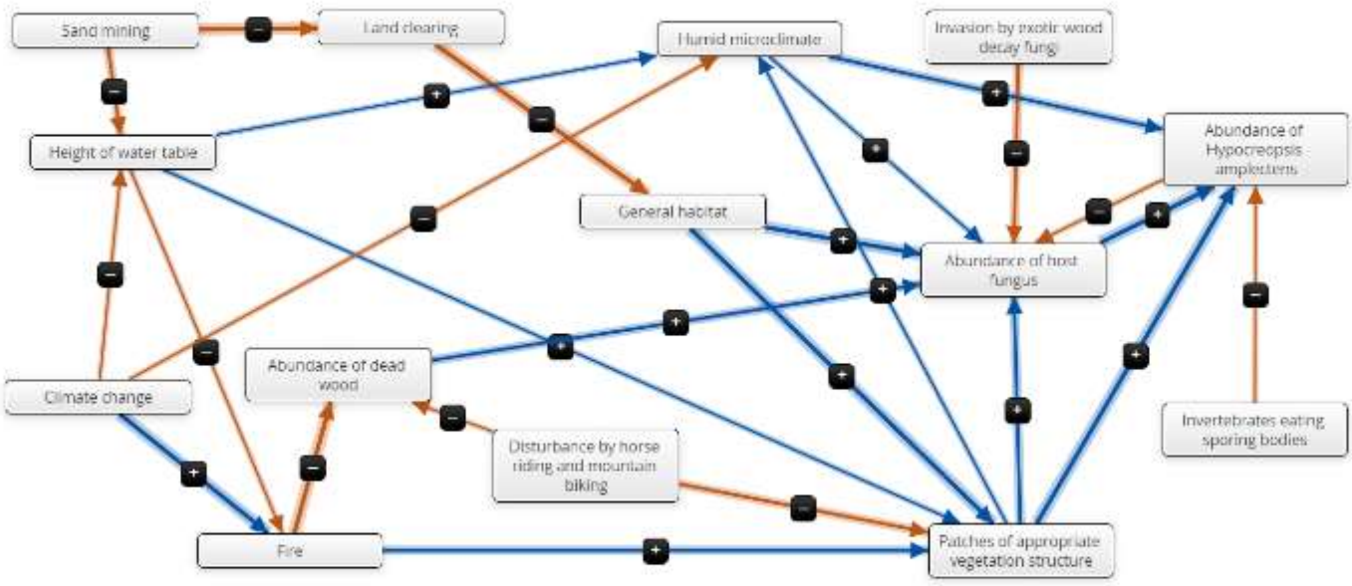

Figure 129. Best case scenario casual model for the effect of climate change and habitat loss on the abundance of *Hypocreopsis amplectens*. Blue arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	Knowledge gap	Proportional reduction
1	The influence of Invertebrates eating sporing bodies on Abundance of Hypocreopsis amplectens	0.428
1	The influence of Invasion by exotic wood decay fungi on Abundance of host fungus	0.428
3	The influence of Fire on Patches of appropriate vegetation structure	0.027
3	The influence of Patches of appropriate vegetation structure on Abundance of host fungus	0.027
3	The influence of General habitat on Abundance of host fungus	0.027
3	The influence of General habitat on Patches of appropriate vegetation structure	0.027
7	The influence of Abundance of Hypocreopsis amplectens on Abundance of host fungus	0.014
7	The influence of Sand mining on Height of water table	0.014
7	The influence of Height of water table on Fire	0.014
7	The influence of Height of water table on Patches of appropriate vegetation structure	0.014
7	The influence of Height of water table on Humid microclimate	0.014
7	The influence of Abundance of dead wood on Abundance of host fungus	0.014
7	The influence of Fire on Abundance of dead wood	0.014
7	The influence of Climate change on Height of water table	0.014
7	The influence of Climate change on Fire	0.014
7	The influence of Climate change on Humid microclimate	0.014
7	The influence of Patches of appropriate vegetation structure on Humid microclimate	0.014
7	The influence of Disturbance by horse riding and mountain biking on Abundance of dead wood	0.014
7	The influence of Disturbance by horse riding and mountain biking on Patches of appropriate vegetation structure	0.014
7	The influence of Humid microclimate on Abundance of Hypocreopsis amplectens	0.014
7	The influence of Humid microclimate on Abundance of host fungus	0.014

Figure 130. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements of climate change and habitat loss on the abundance of *Hypocreopsis amplectens*

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The highest ranked links were the influence of invertebrates eating sporing bodies on *Hypocreopsis amplectens* abundance and invasion of exotic wood decay fungi on the abundance of host fungus. These would therefore make good potential candidates for a research project, as they each represent a large reduction in uncertainty of 0.428.

II. Loss of abundance and diversity of epigeous ectomycorrhizal fungi of Cool Temperate Rainforest due to landscape scale changes

This model describes the effects of climate change and disturbance caused by pest animals, pest fungi and roading on the abundance and diversity of the suite of epigeal ectomycorrhizal fungi of Cool Temperate Rainforest. Important factors are temperature, rainfall and the frequency and intensity of wildfires.

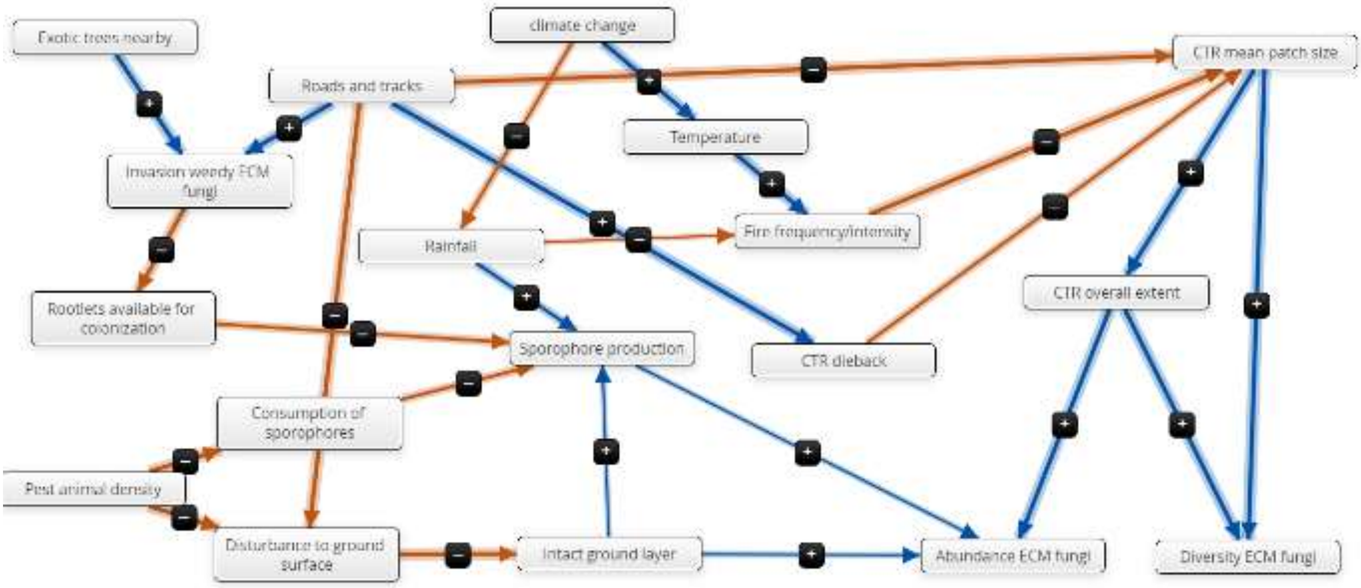

Figure 131. Best case scenario casual model for the effects of climate change and disturbance caused by pest animals, pest fungi and roading on the abundance and diversity of the suite of epigeal ectomycorrhizal fungi of Cool Temperate Rainforest. Blue arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	Knowledge gap	Proportional reduction
1	The influence of Invasion weedy ECM fungi on Rootlets available for colonization	0.077
1	The influence of CTR overall extent on Diversity ECM fungi	0.077
1	The influence of Pest animal density on Consumption of sporophores	0.077
1	The influence of Disturbance to ground surface on Intact ground layer	0.077
1	The influence of Roads and tracks on Invasion weedy ECM fungi	0.077
1	The influence of Roads and tracks on CTR dieback	0.077
7	The influence of Fire frequency intensity on CTR mean patch size	0.038
7	The influence of Intact ground layer on Abundance ECM fungi	0.038
7	The influence of Intact ground layer on Sporophore production	0.038
7	The influence of Rootlets available for colonization on Sporophore production	0.038
7	The influence of Pest animal density on Disturbance to ground surface	0.038
7	The influence of CTR mean patch size on Diversity ECM fungi	0.038
7	The influence of Roads and tracks on CTR mean patch size	0.038
7	The influence of Consumption of sporophores on Sporophore production	0.038
7	The influence of climate change on Rainfall	0.038
7	The influence of Rainfall on Fire frequency intensity	0.038
7	The influence of Rainfall on Sporophore production	0.038
7	The influence of Sporophore production on Abundance ECM fungi	0.038
7	The influence of Exotic trees nearby on Invasion weedy ECM fungi	0.038
7	The influence of CTR dieback on CTR mean patch size	0.038

Figure 132. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements of climate change and disturbance caused by pest animals, pest fungi and roading on the abundance and diversity of the suite of epigeal ectomycorrhizal fungi of Cool Temperate Rainforest.

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The top 6 highest ranked links show a tied value of 0.077, making any one or a combination of these good potential candidates for a research project, as they represent the highest reduction in uncertainty. All other links appear to be second equal candidates for research projects, as they each represent an equivalent reduction in uncertainty of 0.038.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Tea-Tree Fingers (*Hypocreopsis amplectens*) – TTF

Hypocreopsis amplectens – Tea-tree Fingers (TTF) is an ascomycete fungus that forms a macroscopically visible, lobed, stroma that forms finger-like processes, curling around wood. TTF is an obligate parasite on a single species of *Hymenochaetopsis* which is a wood decay fungus forming flat sporing bodies. The *Hymenochaetopsis* host grows on wood, usually dead branches up to several cm in diameter. The wood is often standing, or fallen but caught in the canopy or among other pieces of dead wood and not yet lying flat on the ground. Woody hosts are shrubs to small trees, including *Leptospermum*, *Melaleuca* and *Monotoca*.

Number of experts: 5

Locations:

Geographically, the species is present at three main locations: (1) one population at Wanderslore, near Launching Place, on land managed by the Trust for Nature; (2) four populations in the Westernport Woodlands, three of which are in nature conservation reserves (Adams Creek NCR, The Gurdies NCR and Grantville NCR) and one is on private land on the former Holden Proving Ground; and (3) several populations on French Island, within a National Park.

Current knowledge of TTF indicates that it occurs as low numbers of individuals (judging by the presence of sporing bodies) in small areas in five of six extant populations. At French Island, a larger number of individuals occurs over a wider area.

Actions were designated across the three main locations, specifically at Wanderslore (example of small population on land managed by NGO), Adams Creek NCR (example of small population in Nature Conservation Reserve lacking permanent protection) and French Island (large population in National Park).

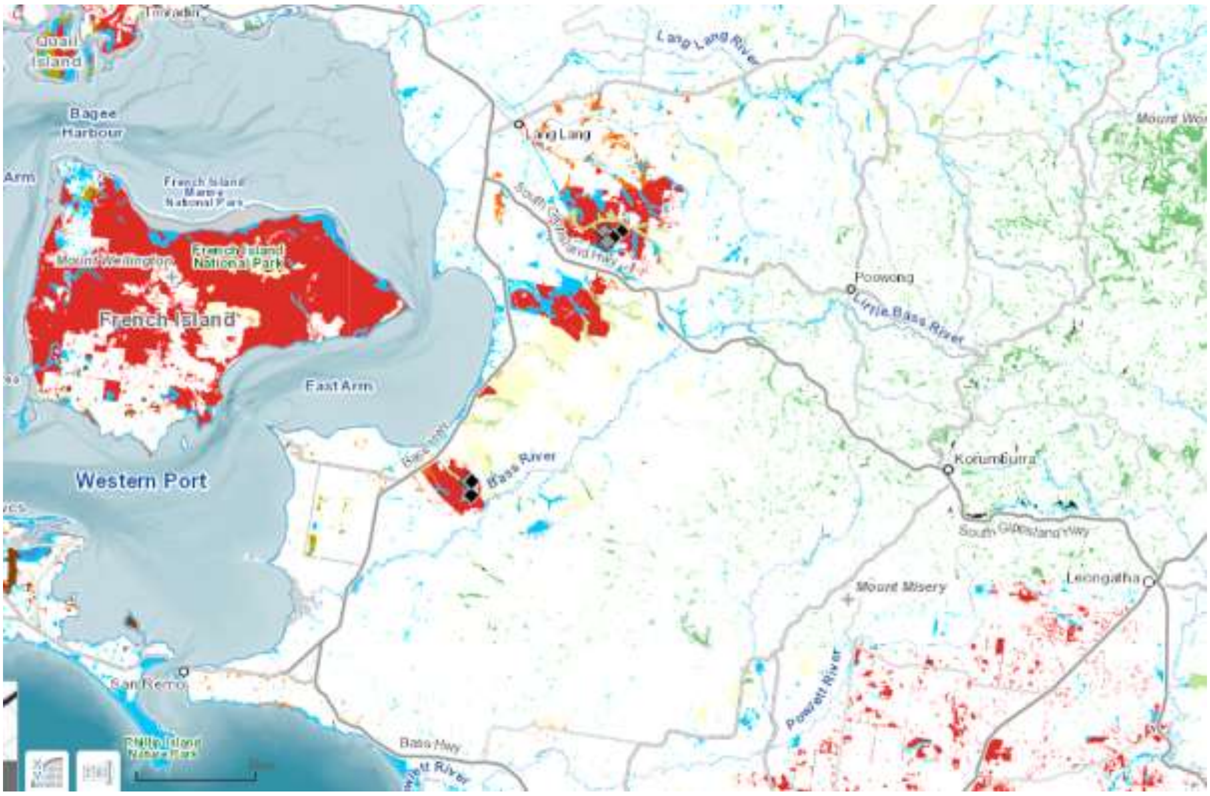

Figure 133. Distribution of *Hypocreopsis amplectens* on the west Gippsland plain (diamonds) from the Victorian Biodiversity Atlas. Only two of four sites on the western shore of Western Port are shown. Adams Creek Nature Conservation Reserve is the northern site, Grantville NCR is the southern site. There are also additional sites on French Island.

SERA planning provision application (proposed): South Gippsland

Figure 134. Proposed South Gippsland Strategic Extractive Resource Area. Note that the position of the current Adams Creek Nature Conservation Reserve (boundaries not indicated on this map) is between the two existing blocks of *Special Use Zone – Extractive Industry* (green shading) and that the Nature Conservation Reserve is included within the *State Resources Overlay* (SR01).

Figure 135. Strategic Extractive Resource Area – Investigation Area in South Gippsland. The Adams Creek Nature Conservation Reserve is not marked, but its rough extent can be seen from the two unshaded blocks that have high scores on the Native Vegetation Condition, that sit between the areas with approved work authorities (blue cross hatching).

#	Actions:	
	No action	As described.

1	Prevent fire	For populations within smaller areas of native vegetation (Wanderslore and the Western Woodland sites) prevent fire encroaching on known populations and surrounding habitat, with buffer of at least 200 m.
2	Prevent disturbance	At The Gurdies there is mountain bike trail construction, not yet impinging on the known population, but in the general area. At several sites, horse riding and bushwalking occurs, and there is evidence of informal tracks, at least one of which is through a known population. Due to TTF occurrence on dead branches that are standing, or partially fallen, any trampling has potential to make these branches fall over and/or break into smaller pieces, and also could lead to opening up of the understorey canopy leading to drying out of substrates. At Wanderslore, there is an existing signed track through the known population. Several methods could be trialled to avoid disturbance, including (1) rerouting tracks, (2) signage and compliance activities to prevent off track activities, and (3) fencing known populations.
3	Add substrate	Take 1-2 m branches from optimum woody substrate (such as *Leptospermum*) and inoculate with host fungus, add 10 substrate units in area 10 x 10 m within existing population, in area where number and density of TTF sporing bodies has been observed to decrease. Need to ensure that added substrate is free of weedy fungi such as *Favolaschia calocera*. Pure cultures of host fungus are available but inoculation technique is not yet worked out. If inoculation was not feasible, could still add substrate units without pre-inoculation with host fungus.
4	Provide permanent protection for nature conservation reserves	Assure permanent protection of sites with known populations in nature conservation reserves. Some of these reserves have been identified in the recent Strategic Extractive Resource Areas Pilot Project, Draft Report (Department of Environment, Land, Water and Planning, Victoria, 2020) as having potential for sand mining, and there is a proposed “State Resource Overlay” that currently sits over the Adams Creek NCR, including known TTF sites. Therefore, there is plausible threat that NCR status could be over-turned. [Postscript: the recently announced boundaries of the South Gippsland Strategic Extractive Resource Area (https://earthresources.vic.gov.au/__data/assets/pdf_file/0006/699360/SERA-Information-for-South-Gippsland.pdf) now exclude the Adams Creek NCR. Nevertheless, the NCR sits within a matrix of land most of which is now earmarked for sand mining]
5	Reintroduction	Should smaller populations die out, translocation of TTF from the larger population on French Island could be considered. Large pieces of substrate with fresh sporing bodies would be removed and placed in areas of suitable habitat (as determined by analysis of vegetation composition and structure at known sites). Translocate 5 individual substrate units, placed within 20 x 20 m area well away from disturbance. One translocation per site. Translocation must take into account potential for spread of pathogens and weedy fungi. Test translocations should be carried out at source sites (moving to nearby suitable habitat), before moving to far distant sites. Ideal to have knowledge of genetic structure when planning translocations (both at source and translocation sites).
6	Create fire mosaic	While fire is damaging in the short to medium term, TTF exists in a landscape where vegetation has evolved with fire. Most known sites are in long unburnt stands (at least 30 years in some cases, and possibly much longer). However, TTF has also been observed in stands from about 20 years post fire. Ultimately, lack of fire may lead to transition of shrubby understorey to grassy understorey, meaning less substrate for TTF – at present there are mixed observations of (1) long unburnt stands converting to grass, sedge and rush ground layer, but also (2)

		stands where the shrubs (Leptospermum) are persistent (McMullan-Fisher, pers. Comm.). Creation of suitable habitat (shrubby understorey) may therefore require fire, although it is uncertain what is the optimum time since fire and fire intensity. In the absence of specific information we can hypothesise that a mosaic of fire ages provides a mix of habitats such that at least some patches are burnt at suitable fire intensity and frequency. The pattern of such a fire mosaic would need to be determined by further research.

Some of these actions (Permanent protection, Fencing) are concrete with clear aims and methodology. Others rely on a considerable amount of further research before they could be implemented (Create fire mosaic). For reintroductions, further background information on the genetic structure of the known populations is required before undertaking translocations to different locations. It would be ideal to test translocation at close distance to known populations first, to establish persistence, over at least a five year period, before attempting reintroductions to other sites. Some experts did not agree that reintroduction should be attempted at all, prior to having more knowledge, hence this action was un-scored by some experts (alone, or in combination with other actions).

Other potential actions

Some further actions were suggested in discussions. Due to lack of background information they are not included in the expert elicitation, but are areas where further research is required.
Further actions include:

Control of weedy fungi	The exotic wood-decay fungus *Favolaschia calocera* is already present at some sites, and spreading rapidly in the general area. Control measures are being investigated but are not yet confirmed (apart from complete removal of infected substrates – which could have a detrimental effect on removal of host fungi for TTF). Further research is required.
Establish new populations from ex situ material	If it was possible to grow TTF ex situ, by obtaining cultures (for inoculation of host), or being able to germinate spores directly on host tissue – then establishment of ex situ populations could be considered, at either known or other sites (using predictive modelling). However, at present it has not been possible to establish cultures of TTF or germinate spores under any conditions. The host fungus grows well in culture, so another approach is to inoculate suitable substrate with the host fungus, and place this at known or other sites, to provide places for TTF to establish. Much further research is required before any of these approaches can be considered.
Grazing by invertebrates	Grazing has been observed by invertebrates. The extent and effect of this is not known. Should it be demonstrated that invertebrate grazing is affecting the population viability, control measures could be considered, such as manual removal of invertebrates or bagging of sporing bodies with fine mesh. Need to take account that depending on stage of grazing, invertebrates could be beneficial as spore dispersers (further research required to establish is dispersal is taking account).
Establish substrate plants	At sites where there appears to be a lack of substrate (the woody shrubs for the host fungus) establish plantings of suitable plants near to known sites. Leave for natural processes to create dead wood, or prune to create dead wood (once suitable diameter branches develop).

For expert elicitation, not all combinations were assessed. In particular, for reintroduction, this would only be effective if fire and disturbance could be prevented and there was permanent protection.

Based on expert assessment the benefit of each action at each location for this species is as follows:

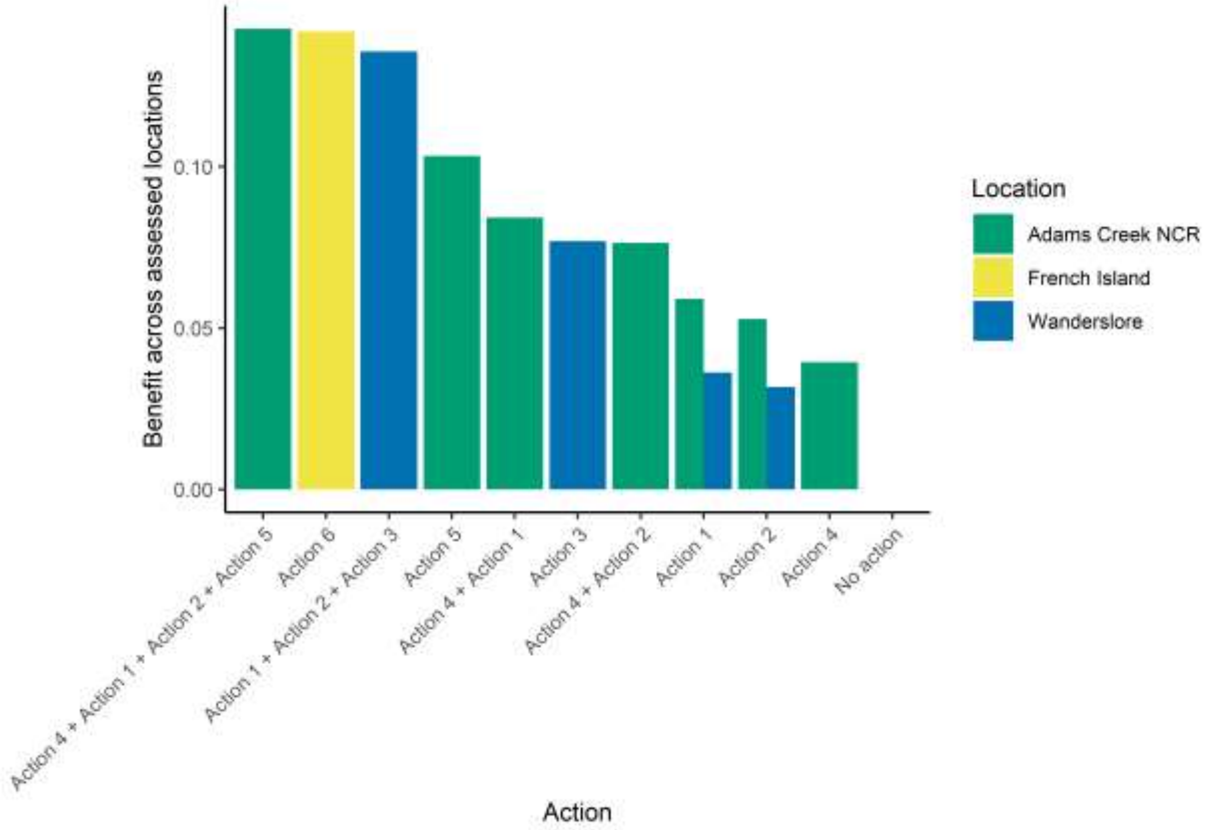

Figure 136. Benefit of each action/location combination to the Tea-Tree Fingers overall persistence probability across all assessed locations.

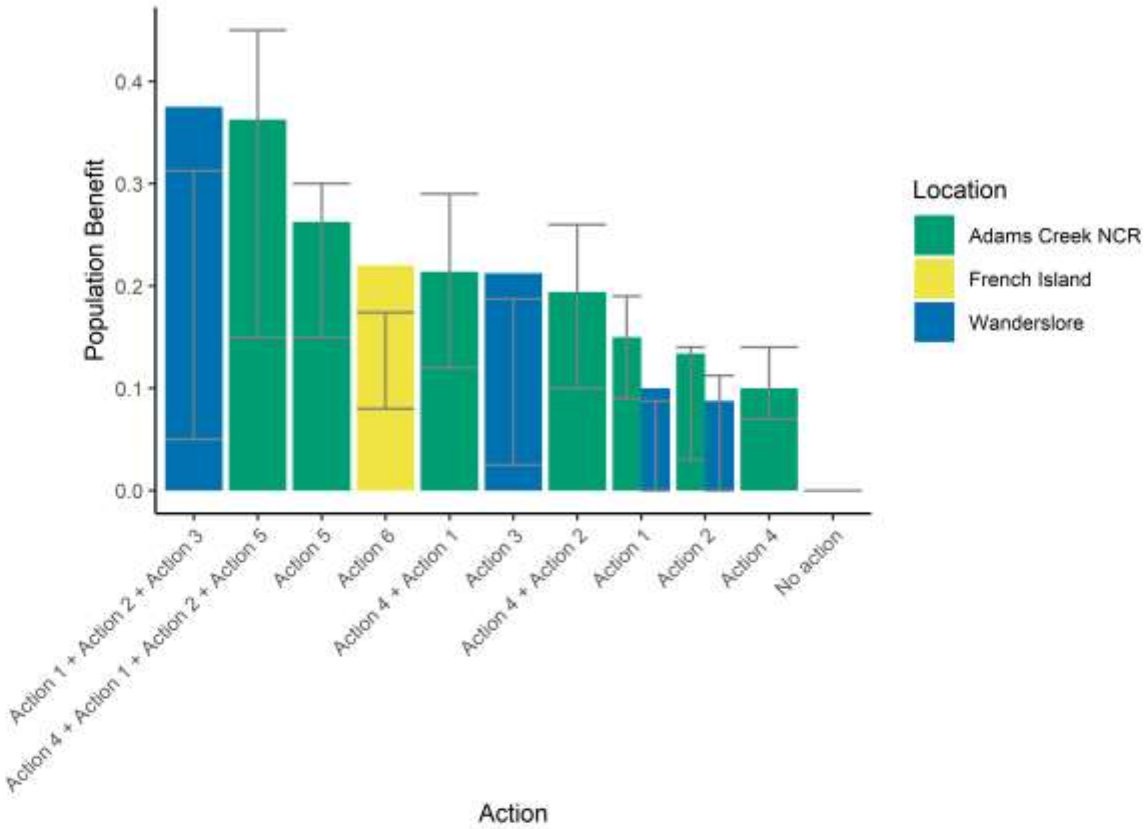

Figure 137. Mean change in Tea-Tree Fingers probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

While the combination of multiple actions demonstrates the highest benefit in Adams Creek and Wanderslore, the greatest individual benefit comes from reintroduction and addition of a substrate respectively. On French Island, creation of fire mosaics is considered the only potentially beneficial management action for this species.

Species: Epigeal ectomycorrhizal fungi (ECM) of Cool Temperate Rainforest (CTR)

Epigeal fungi include mushrooms, coral fungi and other larger fungi that produce above-ground readily visible sporing bodies (sporophores or "fruit bodies"). There are also many hypogeal (underground) ECM fungi, but these are not considered (they are dispersed by mycophagous mammals, and therefore affected by a larger range of factors).

ECM fungi form sporing bodies mostly on the ground but sometimes on tree ferns or dead wood, but still where tree roots are present. Their mycelium forms connections with tree rootlets that facilitate mutually beneficial exchange of nutrients between tree and fungus. ECM fungi are obligate mutualists of host plants across various families, including *Eucalyptus*, *Nothofagus* and *Pomaderris*. Ectomycorrhizal hosts in cool temperate rainforest include *Nothofagus cunninghamii* and *Pomaderris*.

It is not clear if the ECM fungi that are present in CTR forest are obligately symbiotic with *Nothofagus*, or have tight niche tolerances in terms of microclimate, that mirror those of *Nothofagus*. If they are obligately symbiotic, they will disappear when the host disappears. For *Laccaria* sp. "A", this has only been observed in association with *Nothofagus*. However, other ECM species characteristic of CTR, such as *Cortinarius perfoetens*, are occasionally found well away from *Nothofagus* (in this case, in *Eucalyptus* forest in the Wombat Forest). If *Nothofagus* forest is converted to *Eucalyptus* forest, it is therefore possible that some ECM fungi currently associated with CTR could persist in the same locations, but this depends on maintenance of their specific microclimate and microhabitat requirements (such as bryophyte carpets).

Further research is required to characterise the suite of ECM fungi associated with CTR, examine the fidelity of the suite of ECM fungi to this vegetation, understand host specificity and ability to host jump, and determine niche requirements of the ECM fungi.

When assessing the effect of actions on the suite of ECM fungi, the estimates for persistence were carried out on the whole suite, which meant that there could be significant losses of species diversity and abundance that are not able to be captured by the methodology. For the suite of species, due to the way that individual experts interpreted the actions, absolute values may not be strictly comparable, but the relative values are more likely to be comparable.

Number of experts: 6

Locations:

The assessment is for actions specific to the suite of ECM fungi that are totally or largely restricted to CTR in Victoria. Examples are *Laccaria* sp. *A*, *L. masoniae*, *Cortinarius metallicus*, *C. perfoetens*, and *Lactarius albopicri*. It is possible that several dozen more ECM fungi are largely restricted to CTR, but large ECM genera such as *Cortinarius* and *Laccaria* await taxonomic revision.

At present, in Victoria CTR is found in numerous small stands, usually is close proximity to creeks and rivers. Stands often have a dendroid shape due to location at bottom of valleys along drainage lines. There are many hundreds of individual stands, occurring in several broad locations, including the Otway Ranges, the Central Highlands, the Strzelecki Ranges and Wilsons Promontory.

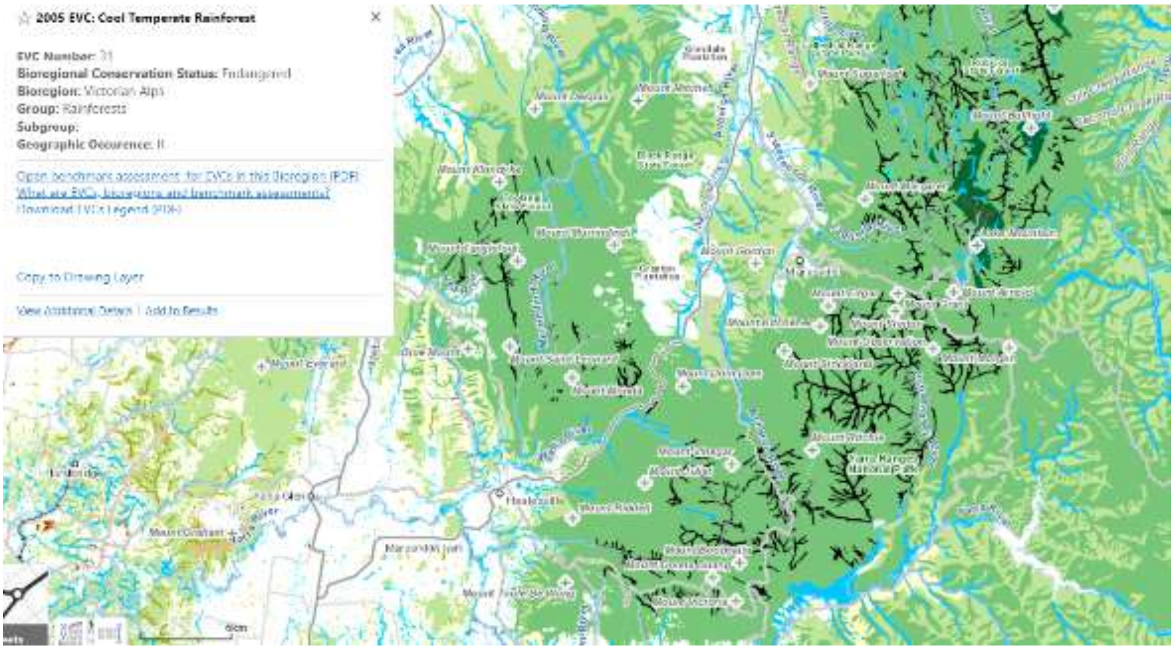

Figure 138. Distribution of the Ecological Vegetation Class (EVC) Cool Temperate Rainforest (black shading) in the northern part of the Central Highlands of Victoria showing scattered, small patches, often with overall dendroid shape. Green shaded vegetation is surrounding *Wet or Damp Forests* (dominated by *Eucalyptus*).

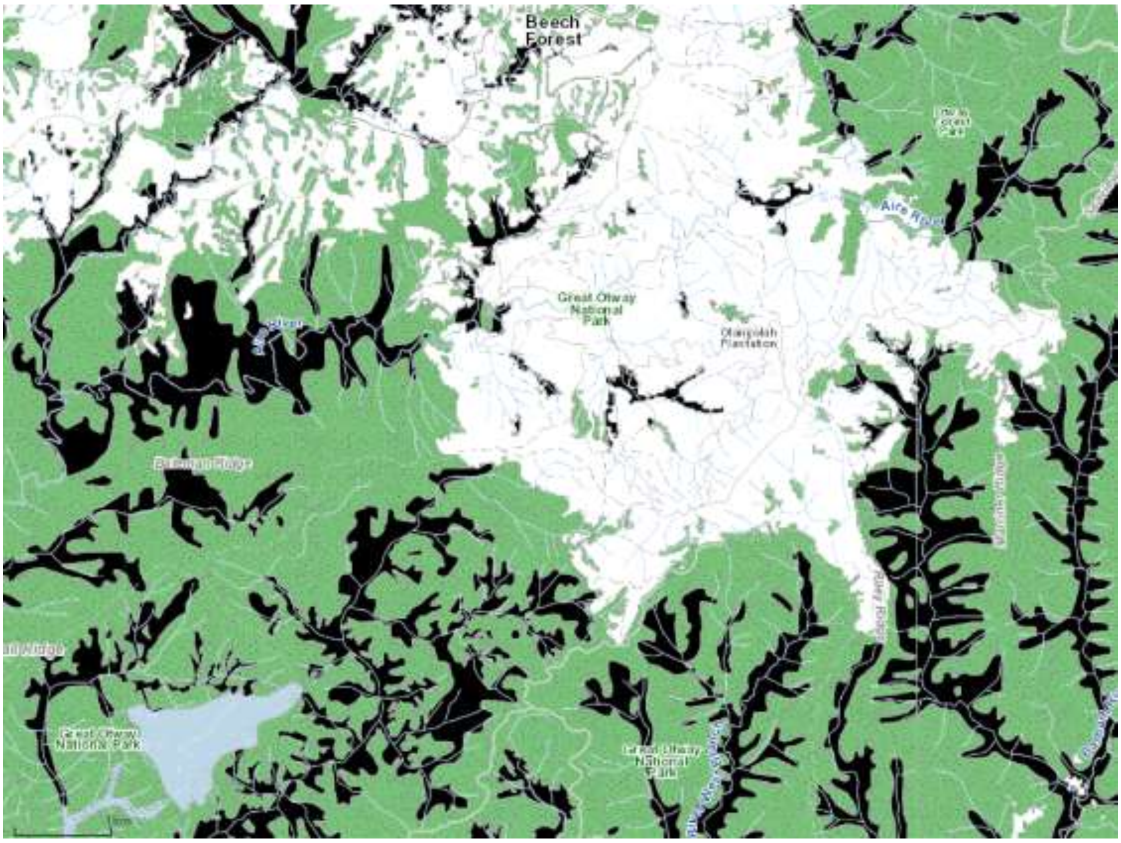

Figure 139. Distribution of the EVC Cool Temperate Rainforest (black shading) in the Otway Ranges south of Beech Forest. Note the scale at 1 km. This area includes some of the largest patches of CTR in the state. Dotted green shaded vegetation is surrounding *Wet or Damp Forests* (dominated by *Eucalyptus*).

There is little information on the exact distribution of ECM fungi in CTR, but the most well-studied species, *Laccaria* sp. A has been found in numerous locations across the whole range of CTR both in Victoria and in Tasmania. It is assumed that the suite of ECM-CTR fungi are found across the range, but the extent to which patch size may affect diversity is not known.

Due to lack of regular disturbance (such as fire) in CTR, ECM fungi could be long-lived and produce large underlying mycelia.

Climate change is a significant risk to CTR through increases in the intensity and frequency of fires. For example, in the O'Shannassy Catchment area to the east of Melbourne, the 2009 fire resulted in loss of 96% of CTR in areas burnt at moderate to high severity, with 889 ha reduced to 33 ha after the fire. In the same catchment, 528 ha burnt at low severity was reduced by 15% to 451 ha.

There is very little information available on which to base actions. Preventing fire, as a general action, is key to the persistence of CTR (as habitat for the ECM community) but the best way to achieve this at landscape and stand levels is not clear.

Control burning is not practical or necessary within CTR stands, as they are likely to be too wet, and even though there may be some post-fire resprouting of some CTR trees, the opening up of the canopy after fire is not desirable, as it may lead to germination and survival of young *Eucalyptus*, which could outcompete the rainforest vegetation.

#	Actions:	
	No action	As described.
1	Avoid disturbance	Avoid placing new roads and tracks within or alongside CTR. There are numerous existing roads and tracks that pass through or alongside CTR. Ensure that road maintenance does not widen existing roads or result in clearance of CTR or mechanical damage to trees.
2	Remove *Eucalyptus*	For the selected large patches of CTR in the Otway Ranges, as suggested by Dell & Casanova (2020) "Remove *Eucalyptus* saplings to 5 m tall within 20 m of rainforest patch edge. … Fell *Eucalyptus* trees within rainforest patch which have a dbh of <10 cm dbh. Repeated every four years".
3	Prevent fire	This is a specific action in relation to selected large patches of CTR in the Otway Ranges. Select four of the largest contiguous patches that are as square as possible (i.e. not long and thin like most patches). Consider distance to roads – need to be close enough to allow easy access for equipment, but preferably not travel through the patches. Use combination of ground irrigation, fire retardant (at margins) and aerial water bombing – in a similar way that fire prevention was carried out for the Wollemi Pine in New South Wales in 2019. Water quality used needs to be considered, so as not to introduce pathogens or alter pH and mineral content of the soil. Apply actions to one or more sites, depending on resources and pattern of fire.

Other potential actions

Further actions discussed that are not considered due to uncertainties in implementation.

Create buffers	Suggested actions for other biota that occur in CTR include planting of broadleaf indigenous shrubs and canopy species to 70% total site cover as a 100 m buffer. This may well be worth considering for ECM-CTR, if suitable sites could be selected, based on maximal species diversity, and knowledge of effect and effectiveness of this approach. However, there is insufficient information at the moment to specify potential sites. Planting of

	buffers may be more appropriate where there is already considerable disturbance around a site, and could be used where rehabilitation is occurring, such as closing off roads, or clearing adjacent plantations. If surrounding *Eucalyptus* forest was to be cleared, it would need to be demonstrated that this is not detrimental, in relation to opening up the canopy and causing drying out of the CTR in the interval between planting of the buffer and it reaching maturity.
Close roads	For roads that are not main roads, that impinge on large intact patches of CTR, consider closing off, with access by management vehicles only.
Fire suppression in surrounds	Implement fire suppression activities in surrounding forest to prevent wildfire travelling from surrounding forest into CTR. For example, planned burning of surrounding mixed species forest. Note that burning of such forest may in fact increase the proportion of sclerophyll species in relation to rainforest species in that surrounding forest. Such control burning of immediately surrounding wet forest could be impractical, as there would only be narrow windows for burning and too much risk of fire burning into the CTR stands.

Because a group of species is being assessed, the actions for the Whole extent are assessed against 90% of the species present remaining at 90% of sites where currently present.

For the Otway large patches (four patches), actions are assessed against the aim of 90% of species retained across the four sites where actions are carried out.

Based on expert assessment the benefit of each action at each location for this species is as follows:

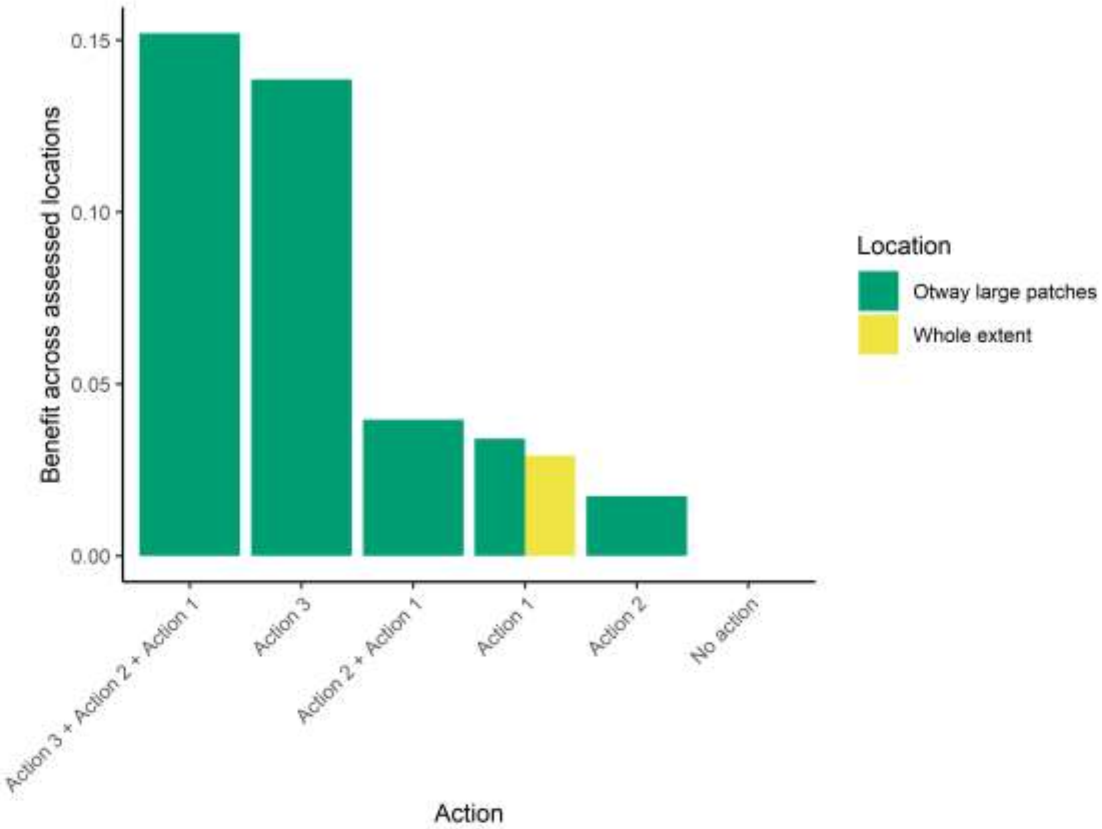

Figure 140. Benefit of each action/location combination to the Epigeal ectomycorrhizal fungi overall persistence probability across all assessed locations.

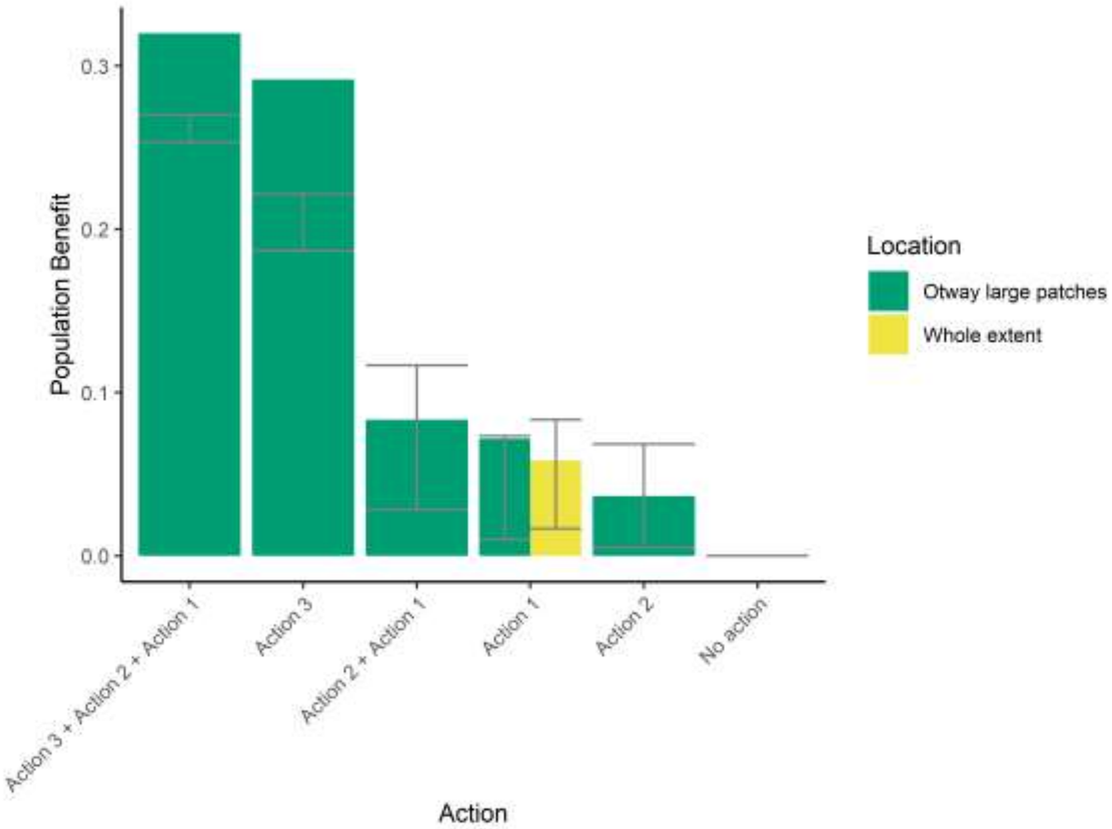

Figure 141. Mean change in Epigeal ectomycorrhizal fungi probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

In the Otway large patches, prevention of fire is considered by far the most beneficial action, almost equivalent to the combination of all actions. When considering the whole extent, avoiding disturbance from roads and tracks is the only action which was considered as having a potential beneficial.

Invertebrate functional groups

Introduction

The diversity and number of invertebrate species in Victoria coupled with the limited knowledge of this group made the task of selecting species for Specific Needs analysis difficult. Experts at the invertebrate workshop identified potential species or species groups of interest. This initial list required further refinement according to the following principles:

- At least part of the life cycle is reliant on terrestrial habitats
- The species is endemic to Victoria or the Victorian population(s) are important to the overall conservation of the species
- The species is known from one or more discrete locations that could be succinctly described to the experts
- Species specific threats and actions were identified at the workshop and/or published conservation advice was available (e.g. Action Statements, Recovery Plans), and
- At least one expert could be identified that was familiar with the species in the wild (as opposed to purely its taxonomy).

Consideration was also given to a getting a range of taxonomic groups and location and habitats, as a result five species were selected.

See supplementary report for reference material and further information.

Key knowledge gaps

I. Effect of climate change on fire

This model explores how climate change alters the effects of fire. As that fire interacts with other disturbances in the system (chemical use, roading) and management actions (permanent protection, planned burns) this produces a collective impact on invertebrate persistence, as dictated by ability to survive to adulthood and reproduce.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

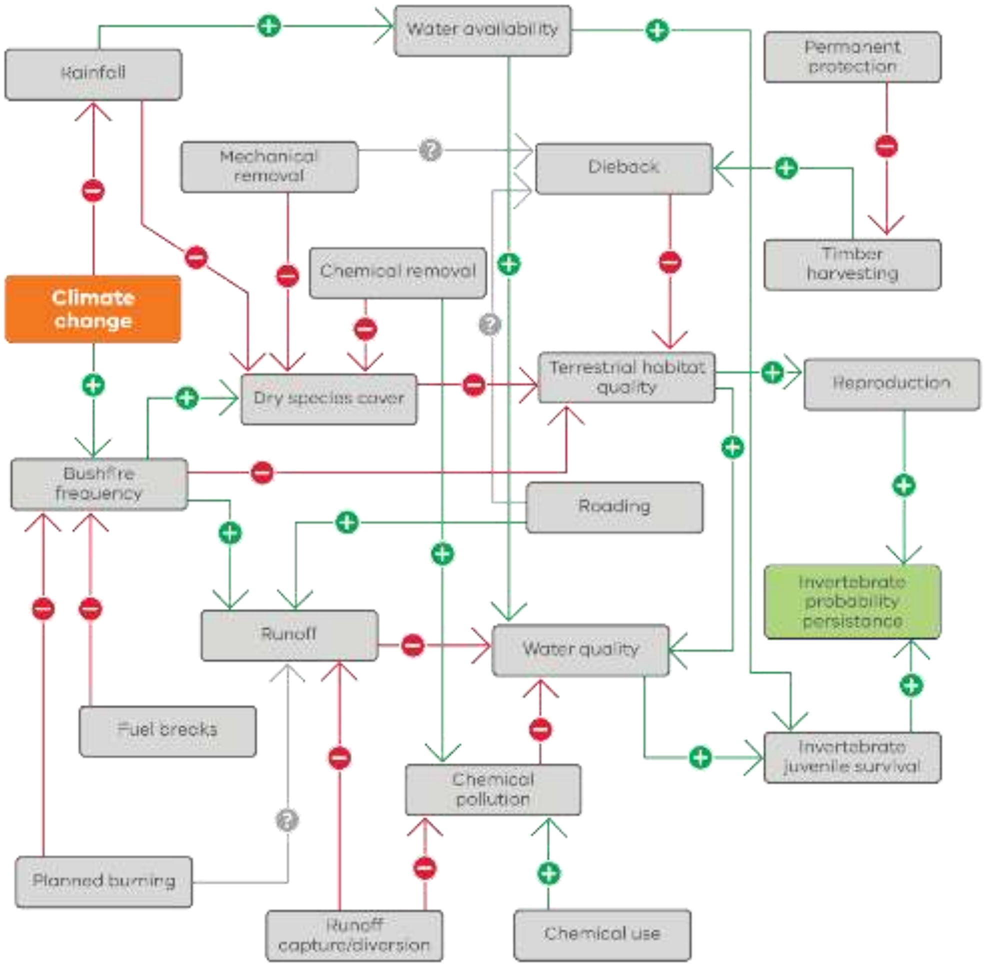

Figure 142. Best case scenario casual model for effect of climate change on fire. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

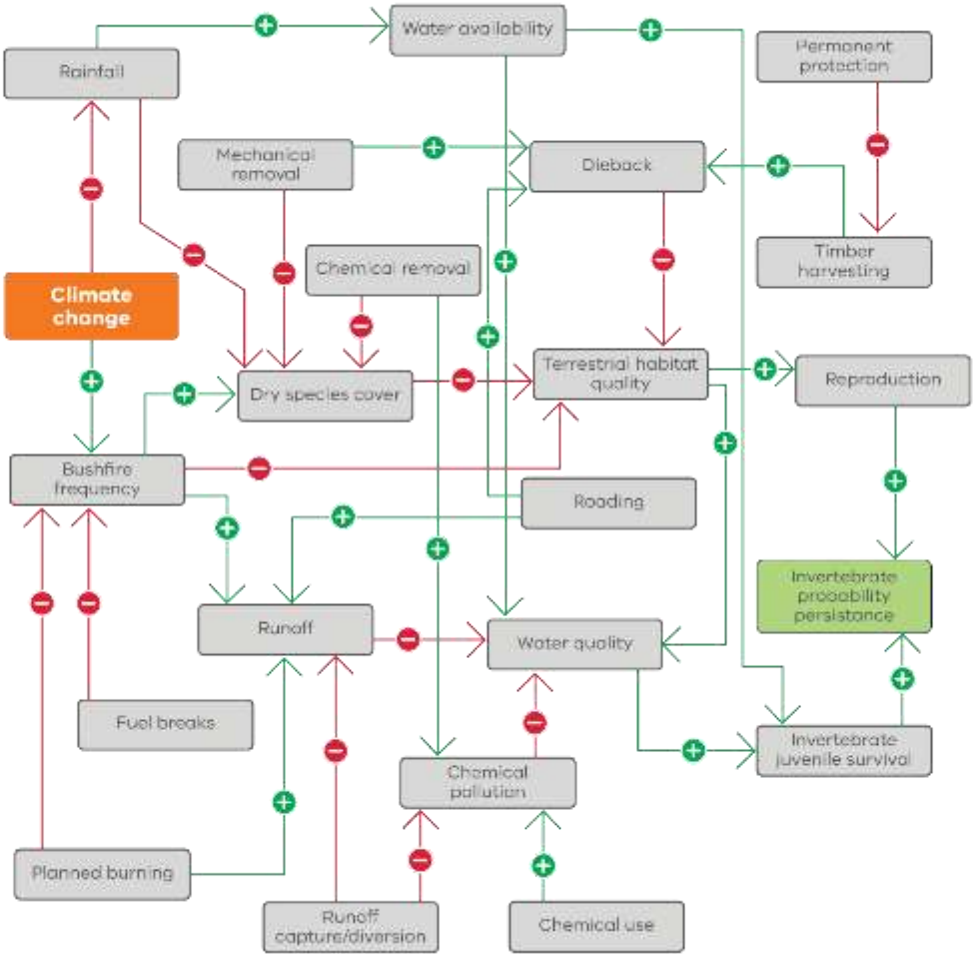

Figure 143. Worst case scenario casual model for effect of climate change on fire. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Bushfire frequency	Dry spp cover	0.061
1	Roading	Dieback	0.061
1	Dieback	Terrestrial habitat quality	0.061
1	Timber harvesting	Dieback	0.061
1	Terrestrial habitat quality	Water quality	0.061
1	Runoff capture diversion	Runoff	0.061
1	Runoff capture diversion	Chemical pollution	0.061
1	Fuel breaks	Bushfire frequency	0.061
9	Rainfall	Dry spp cover	0.030
9	Climate change	Rainfall	0.030
9	Climate change	Bushfire frequency	0.030
9	Water availability	Juvenile survival	0.030
9	Mechanical removal	Dieback	0.030
9	Chemical removal	Dry spp cover	0.030
9	Chemical removal	Chemical pollution	0.030
9	Dry spp cover	Terrestrial habitat quality	0.030
9	Planned burning	Bushfire frequency	0.030
9	Planned burning	Runoff	0.030
9	Bushfire frequency	Runoff	0.030
9	Bushfire frequency	Terrestrial habitat quality	0.030
9	Runoff	Water quality	0.030
9	Roading	Runoff	0.030
9	Terrestrial habitat quality	Reproduction	0.030
9	Chemical pollution	Water quality	0.030
9	Water quality	Juvenile survival	0.030

Figure 144. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for climate change on fire

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The highest ranked links were bushfire recovery on dry species cover, roading on dieback on terrestrial habitat quality, timber harvesting on dieback, terrestrial habitat quality on water quality, runoff capture diversion on runoff and chemical pollution, and fuel breaks on bushfire frequency. These might be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.061.

II. Effect of conservation translocation on probability of persistence

This model explores the key elements which must be considered to successfully conduct a conservation translocation to improve probability of persistence. While this applies to invertebrate species, the genetic and metapopulation principals are broadly generalisable.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

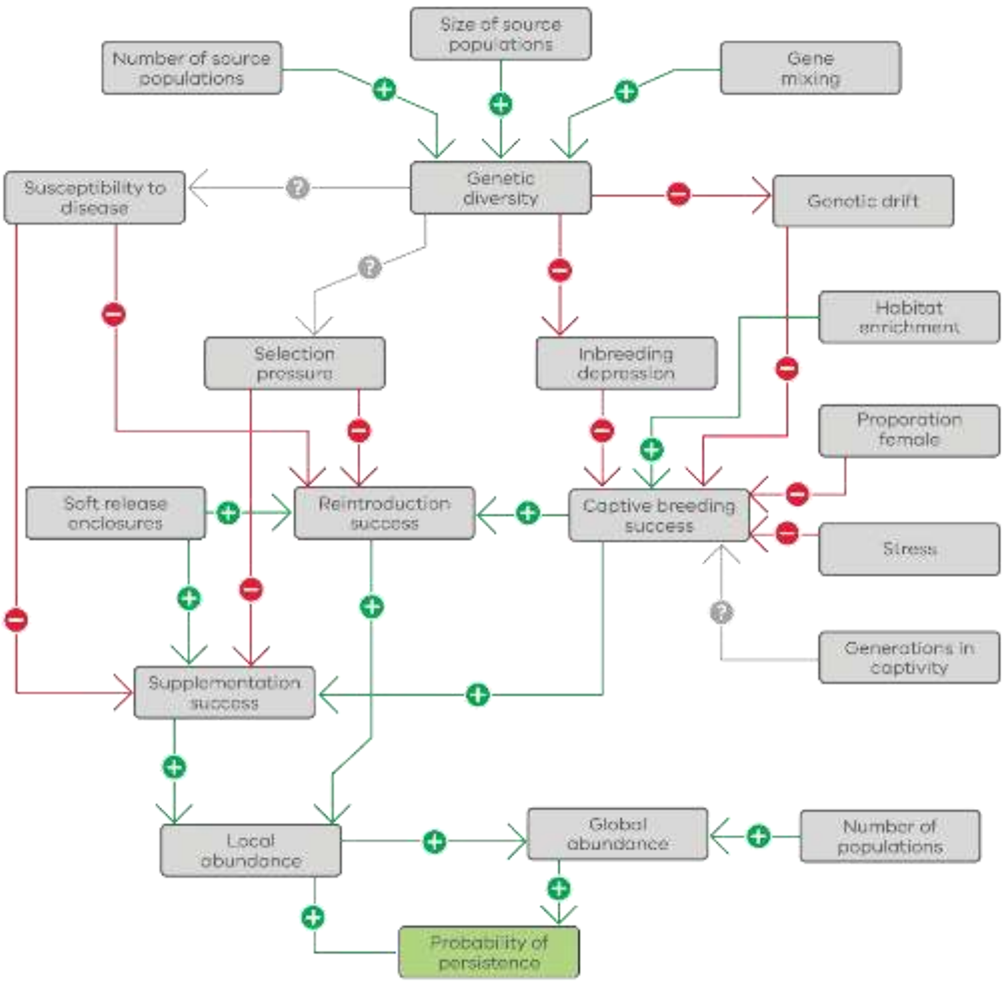

Figure 145. Best case scenario casual model for effect of conservation translocation on probability of persistence. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

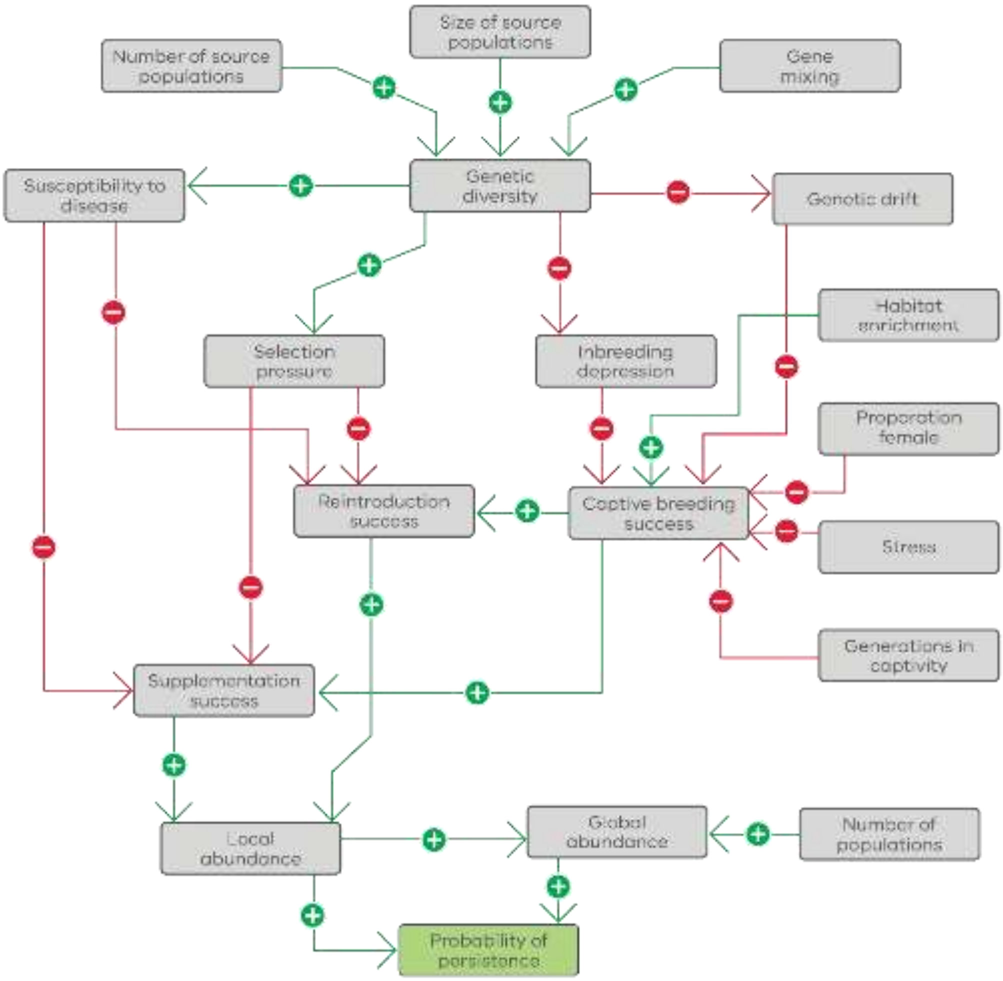

Figure 146. Worst case scenario casual model for effect of conservation translocation on probability of persistence. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Generations in captivity	Captive breeding success	0.408
2	Soft release enclosures	Reintroduction success	0.390
2	Soft release enclosures	Supplementation success	0.390
4	Genetic diversity	Susceptibility to disease	0.020
4	Genetic drift	Captive breeding success	0.020
4	Habitat enrichment	Captive breeding success	0.020
4	Prop female	Captive breeding success	0.020
4	Stress	Captive breeding success	0.020
9	No of source pops	Genetic diversity	0.010
9	Source pop size	Genetic diversity	0.010
9	Gene mixing	Genetic diversity	0.010
9	Genetic diversity	Selection pressure	0.010
9	Genetic diversity	Inbreeding depression	0.010
9	Genetic diversity	Genetic drift	0.010
9	Susceptibility to disease	Reintroduction success	0.010
9	Susceptibility to disease	Supplementation success	0.010
9	Selection pressure	Reintroduction success	0.010
9	Selection pressure	Supplementation success	0.010
9	Inbreeding depression	Captive breeding success	0.010
9	Captive breeding success	Reintroduction success	0.010
9	Captive breeding success	Supplementation success	0.010
9	Reintroduction success	Local abundance	0.010
9	Supplementation success	Local abundance	0.010
9	Local abundance	Global abundance	0.010
9	Local abundance	Prob persistence	0.010
9	No of pops	Global abundance	0.010

Figure 147. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for conservation translocation on probability of persistence.

The highest ranked links were generations in captivity on captive breeding success, and soft release enclosures on reintroduction success and supplementation success. These might be good candidates for research projects, as they represent the highest reduction in uncertainty of 0.408 and 0.39 respectively.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Giant Gippsland Earthworm (*Megascoliodes australis)*

Number of experts: 1

Locations:

South and West Gippsland

Current population in Victoria: Giant Gippsland Earthworm is endemic to an area of south and west Gippsland or about 40,000 ha. For the elicitation this was considered a single population.

#	Actions:	
	No action	As described.
1	Permanent protection	Permanent protection of known locations, this includes prohibition against soil disturbance.
2	Prevent cultivation	Prohibit soil cultivation in known habitat.
3	Prevent soil disturbance	Prevent all soil disturbance in known locations. Prevent compaction of soil from all sources including stock agricultural vehicles etc. at times of the year soil moisture is high, moisture is high when the impact is likely to collapse the soil damaging habitat.
4	Avoid pesticide	Avoid spraying of herbicide for weed control within catchment of known locations. Require alternative weed control.
5	Eliminate wastewater	Eliminate all sources of pollution from domestic wastewater sources.
6	Eliminate stormwater	Upgrade stormwater systems to eliminate runoff.
7	Restoration	Restoration of native vegetation according to the DELWP standard for the relevant EVC.

Based on expert assessment the benefit of each action at each location for this species is as follows:

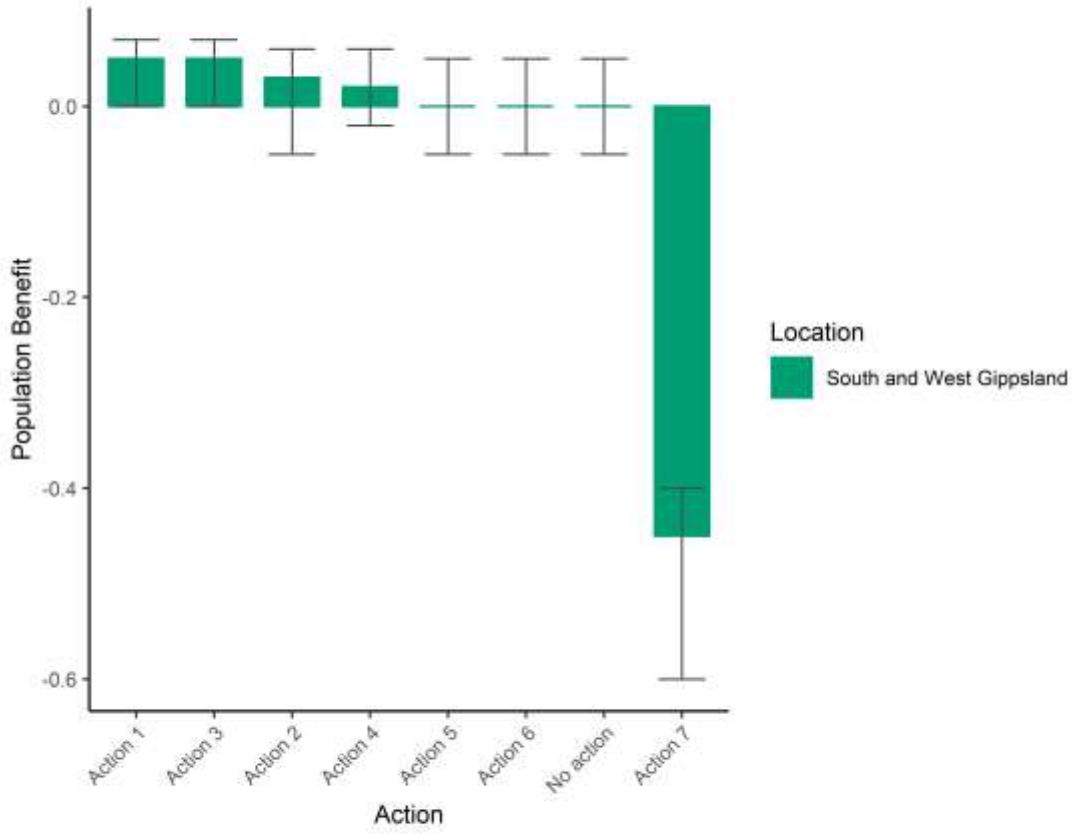

Figure 148. Mean change in Giant Gippsland Earthworm probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Experts did not predict high benefit from any of the suggested actions for the Giant Gippsland Earthworm. Instead, they predicted a large disbenefit of restoring native vegetation, suggesting this work should not be carried out in critical areas or for the purposeful impact of the species. Restoration action shows a negative benefit as experts assessed the probability of persistence under a no action scenario as higher than under this management action scenario.

Species: Otway Black Snail (*Victaphanta compacta)*

Number of experts: 1

Locations:

Otway Ranges

Current population in Victoria: Otway Black Snail is known only from the Otway Ranges, for this exercise this was considered a single population.

#	Actions:	
	No action	As described.
1	Permanent protection	Permanent protection of known locations.
2	Cease roading	Cessation of roading activities in known locations.
3	Fire suppression	Fire suppression activities in surrounding forest prevent burning of habitat, including but not limited to planned burning of surrounding mixed species forest.

Based on expert assessment the benefit of each action at each location for this species is as follows:

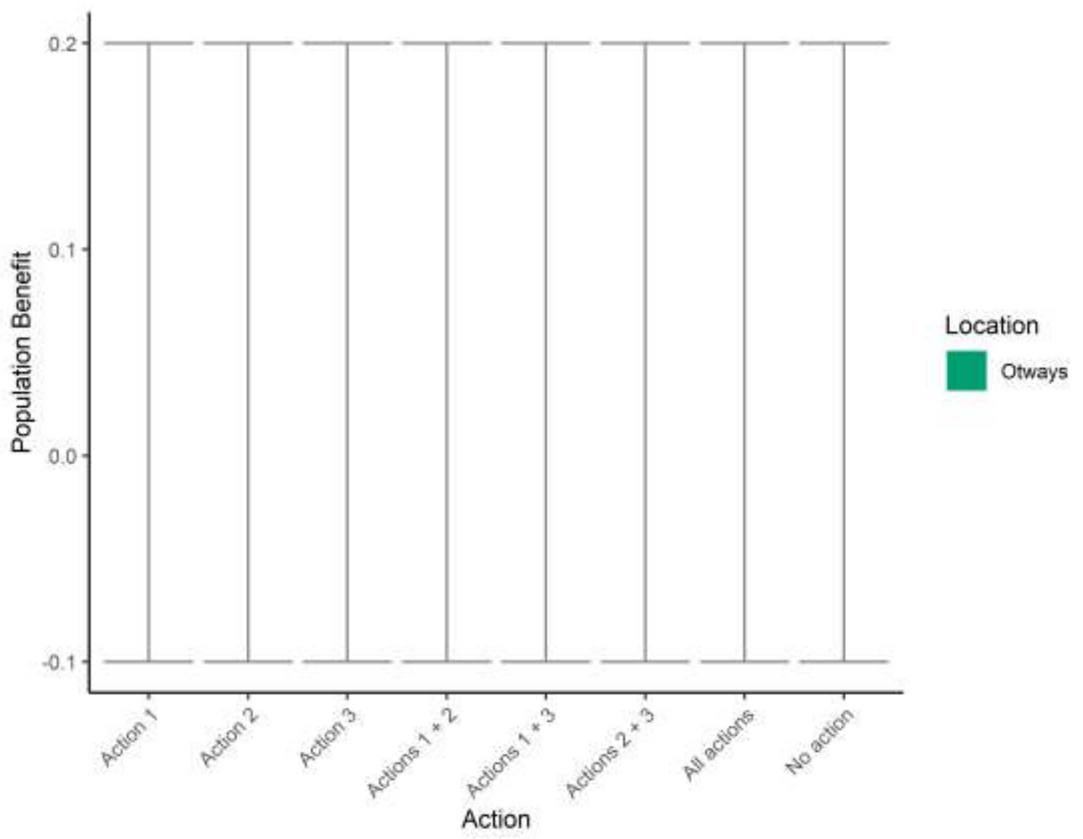

Figure 149. Mean change in Otway Black Snail probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

No benefit was described for any action for this species. More work is required to determine an effective action.

Species: Ancient Greenling Damselfly (*Hemiphelbia mirabilis)*

Number of experts: 2

Locations:

South West Victoria, Grampians, Buxton, and Wilson’s Promontory

Current population in Victoria: Known from four locations in Victoria; the far south west of the state, the Grampians, Buxton, and Wilson’s Promontory. These populations were considered as separate for the elicitation.

	Actions:	
	No action	As described.
1	Shrub control	Surveillance and removal of shrubs in problem areas, particularly Coast Wattle and Wooly Tea-Tree.
2	Mow	Annual mowing of fuel breaks adjacent to swamps outside of flight season (Nov-Feb).
3	Restoration	Restoration of native vegetation according to the DELWP standard for the relevant EVC.

Based on expert assessment the benefit of each action at each location for this species is as follows:

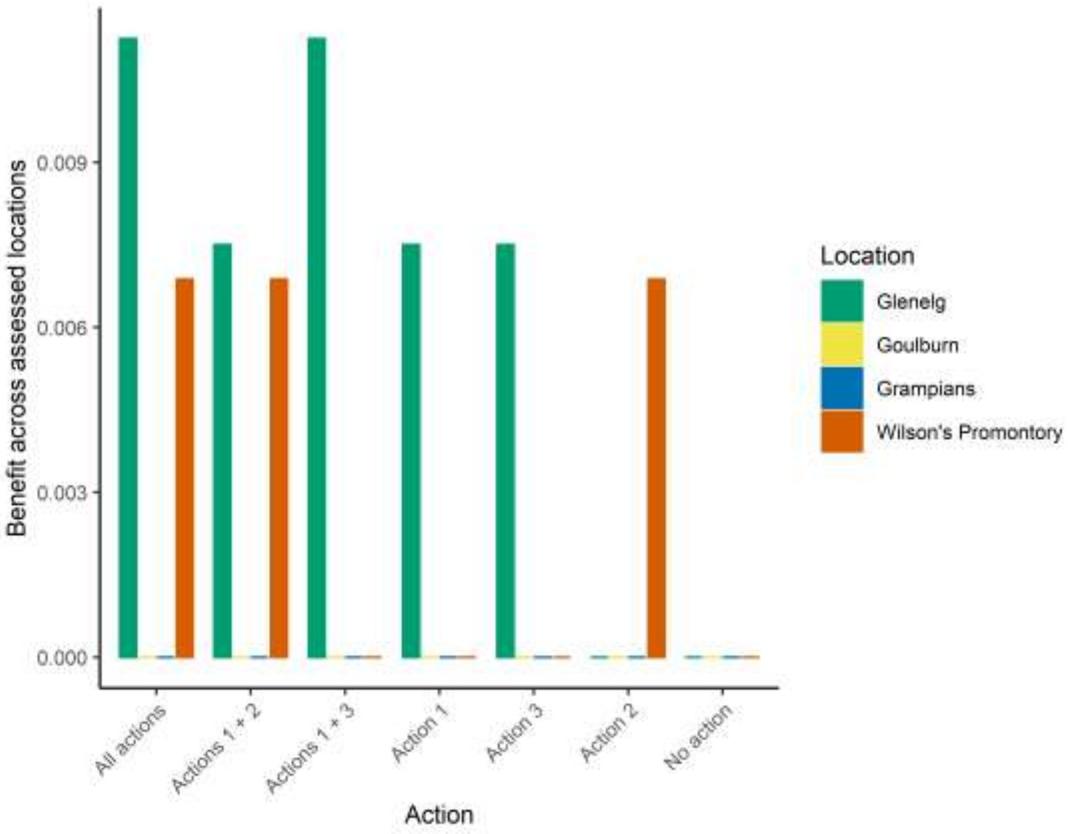

Figure 150. Benefit of each action/location combination to the Ancient Greenling Damselfly overall persistence probability across all assessed locations.

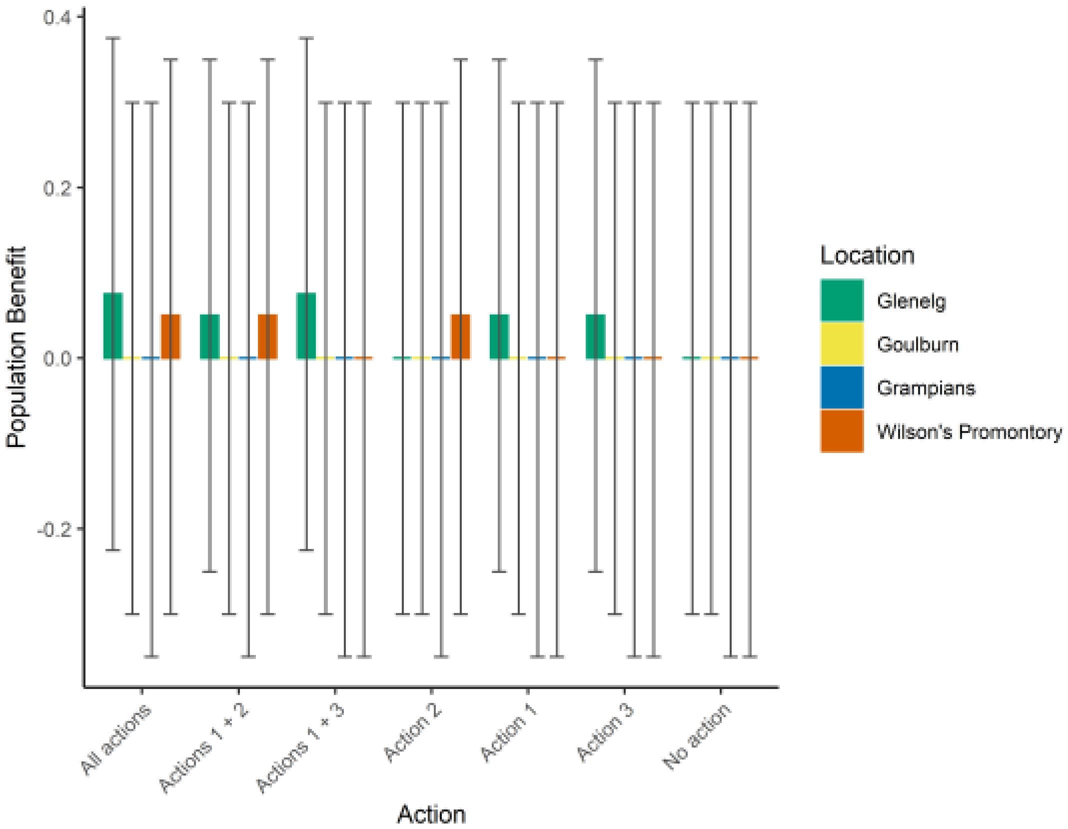

Figure 151. Mean change in Ancient Greenling Damselfly probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Results for this species suggest that there is little opportunity for benefit from any action in Goulburn or the Grampian. Management should therefore be targeted to Glenelg and Wilson's Promontory to improve the Ancient Greenling Damselfly's probability of persistence.

Species: Alpine Stonefly (*Thaumatoperla alpine)*

Number ofexperts: 4

Locations:

Bogong High Plains

Current population in Victoria: Alpine Stonefly is known from several locations at high altitude on the Bogong High Plains, all populations were considered together for the elicitation.

#	Actions:	
	No action	As described.
1	Trout control	Best practice trout control involves the modification of instream barriers to prevent trout incursion, and then undertaking annual predator (trout) detection and removal activities.
2	Stream buffer	Protection of 10m buffer around streams.
3	Permanent protection	Permanent protection of known locations, includes protection from resort development and stream buffer.
4	Resort protection	Protect habitat from resort development.
5	Eliminate runoff	Improve drainage to divert/capture runoff.

Based on expert assessment the benefit of each action at each location for this species is as follows:

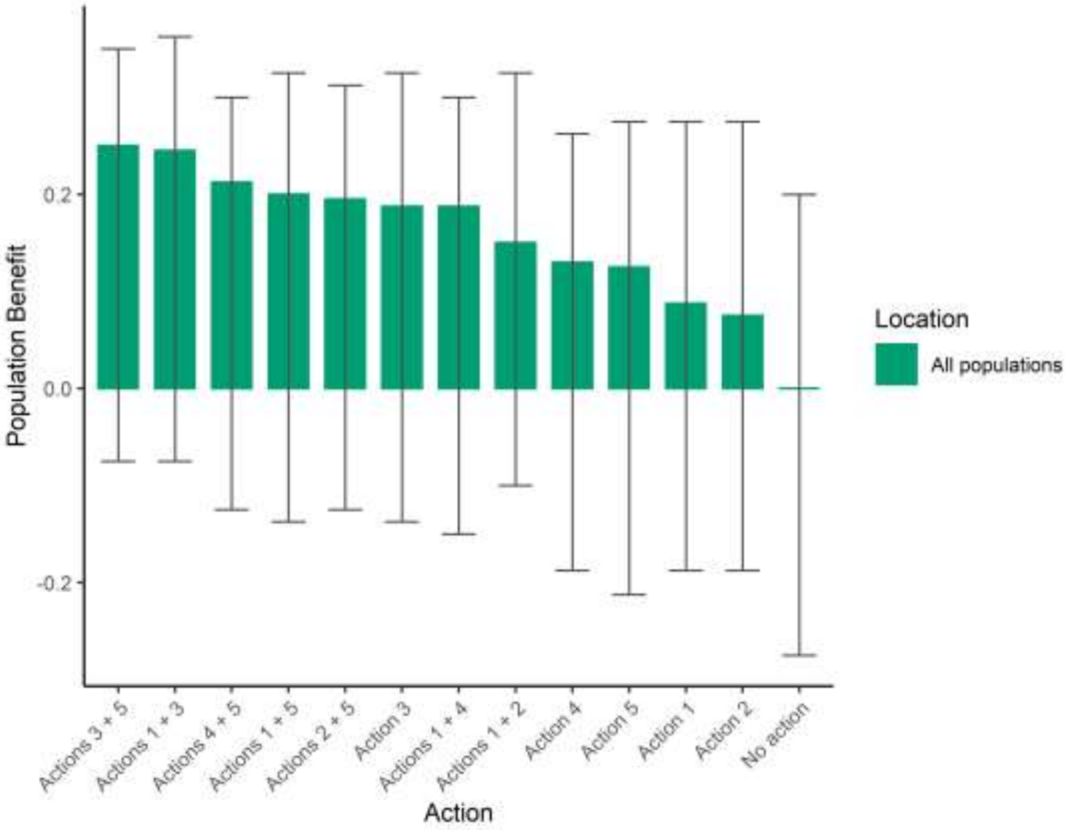

Figure 152. Mean change in Alpine Stonefly probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Benefit values for Alpine Stonefly actions vary by approximately 0.1 from best to worst. Permanent protection appears to be the most beneficial single action and is improved by the contribution of trout control or eliminating runoff.

Species: Dandenong Burrowing Crayfish (*Engaeus urostrictus)*

Number of experts: 2

Locations:

Dandenong Ranges

Current population in Victoria: Dandenong Burrowing Crayfish is known from one location, the Dandenong Ranges.

#	Actions:	
	No action	As described.
1	Fire suppression	Fire suppression activities in surrounding forest prevent burning of habitat, including but not limited to planned burning of surrounding mixed species forest.
2	Avoid pesticide	Avoid spraying of herbicide for weed control within catchment of known locations. Require alternative weed control.
3	Eliminate wastewater	Eliminate all sources of pollution from domestic wastewater sources.
4	Eliminate stormwater	Upgrade stormwater systems to eliminate runoff.
5	Control deer	Sustained deer control (shooting) in and surrounding known locations, suppression of population.

Based on expert assessment the benefit of each action at each location for this species is as follows:

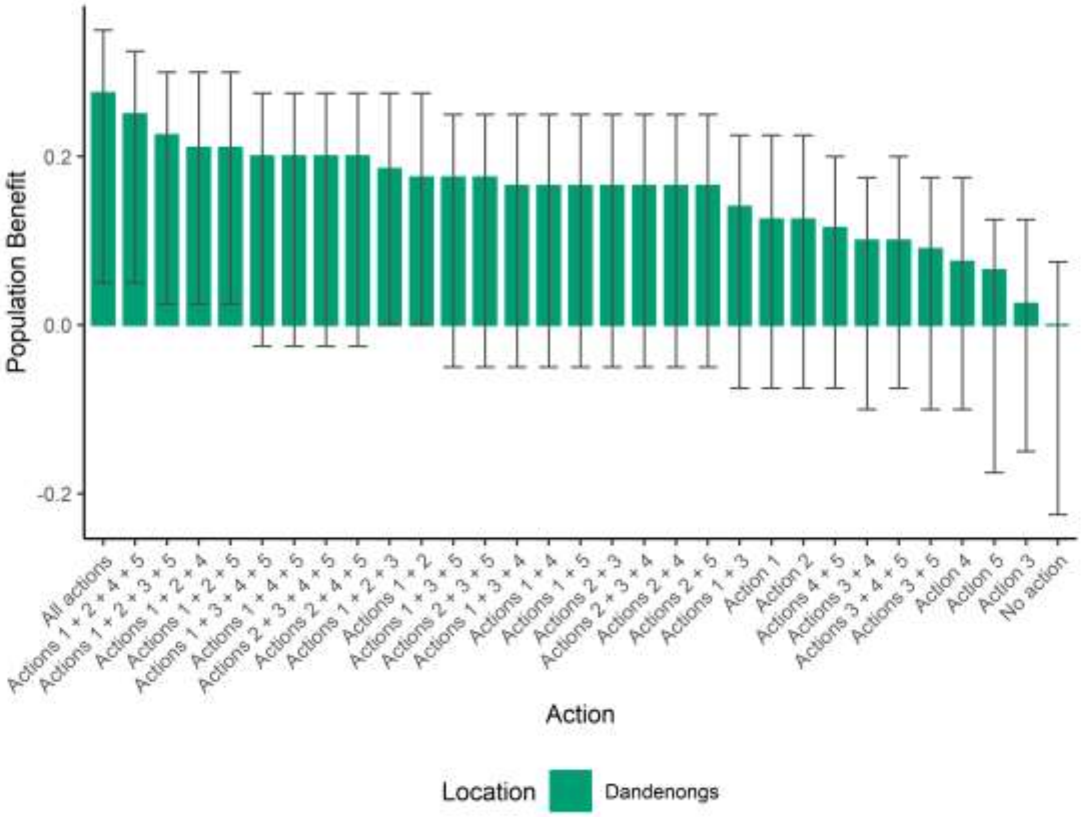

Figure 153. Mean change in Dandenong Burrowing Crayfish probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Many actions and combinations were considered for the Dandenong Burrowing Crayfish, with the ranked benefit showing a gradual decline in value. When implementing management, consideration should be given to which combination of actions are most cost-efficient and can realistically occur under a given budget and jurisdiction. The most beneficial single action is fire suppression, highlighting fire as the major manageable threat.

Native rodents and small marsupials

Introduction

This taxon is represented by five species, each exploring a different key factor which guides the management planning and perspective. This selection allows a unique investigation of the benefits of action (or combinations of actions) which both is highly revelling of the nuisance of the scenario but is also generalisable to other species which experience comparable conditions. These factors are:

- Actions in a metapopulation context (Broad-Toothed Rat)
- Actions with knowledge (Smoky Mouse)
- Translocation benefit (New Holland Mouse)
- Connectivity in mixed landscapes (Fat-Tailed Dunnart)
- Connectivity in fire managed landscapes (Mallee Ningaui)

Key knowledge gaps

I. Impact of inappropriate fire on small mammal abundance

The first problem-response scenario determined for native rodents and small marsupials in Victoria is 'habitat quality and fire'. We constructed an 'inappropriate fire' causal model consisting of one key objective separated into three components, one threat, one external modifier, 14 processes and 10 management actions. The key objective of the model is to increase the abundance of small mammals through increased survival, reproduction, and colonisation (see 'translocations' model below). Several key questions are addressed by this model and highlight current knowledge gaps. These include:

- What are the impacts of fire and different types of fire? Need to be able to track abundance, movement, and survival of target species in both burnt and unburnt areas to acquire knowledge about bushfire impacts and resilience of species to these.
- How does species-specific habitat recover after fire? How much of this habitat remains after fire and how much habitat does each species require?
- What other threats are populations which are surviving in, or adjacent to, burnt areas susceptible to? Are the impacts of these threats more pronounced on these populations?
- What are the impacts of feral herbivores and feral predators on populations in burnt and unburnt habitats? How do these impacts differ between the two habitat types?
- What are the impacts of competition from introduced rodent species in burnt and unburnt habitat?
- What fire regimes are different species accustomed to?

Fire can be beneficial (appropriate) or destructive (inappropriate) depending on the regime of the fire (i.e. location, extent, frequency, intensity, season). Both are complex – here we treat them separately to capture the duality of fire with inappropriate fire identified as the key threat in the causal model.

Appropriate fire can be beneficial to both animals and plants through processes such as triggering germination, reducing competition for seedlings by clearing dense understorey vegetation, encouraging new growth providing important food sources for many animals and creating hollows in trees and logs for use as shelter and nest sites. Fewer appropriate fires and increased vegetation (fuel load) within a landscape can increase the negative impact of inappropriate fire on the ecosystem. A healthy herbivore community drives both of these modifiers by reducing the fuel load within the environment. Management actions to achieve appropriate fire within the landscape, and thus reduce the impacts of inappropriate fire, include implementing prescribed burns characterised by appropriate fire regimes (timing, frequency, location, extent) at specified locations as well as implementation of native herbivore management, such as fencing, capture and translocation and contraception, to support healthy herbivore communities.

Inappropriate fire is increasing in frequency within Australia and it is widely accepted that a warming and drying climate (external modifier) is greatly increasing the probability of its occurrence as well as increasing the different components of the fire regime: fire season length, fire intensity, fire frequency and fire extent (size and uniformity). These components are all modifiers of inappropriate fire impact.

Inappropriate fire has a direct impact on the abundance of small mammals by decreasing the:

- Probability of survival of individuals due to direct mortality or depletion of critical resources (i.e. species-specific food items and shelter) within the post-fire environment.
- Probability of reproduction due to depletion of critical resources required for reproduction within the post-fire environment.
- Colonisation capabilities of individuals in the post-fire environment due to habitat destruction/modification, depletion of critical resources and increased predation and competitive pressures. Management includes various translocation strategies to increase small mammal abundance at a site including wild-to-wild, captive source and rescue and release (see *Translocations* model for further details).

Inappropriate fire also has numerous direct effects on several habitat characteristics and community interactions with seven management actions identified to overcome these threatening processes including:

1. Decreasing the availability of species-specific shelter within the post-fire environment. Physical shelter offers protection to animals from the physical environment as well as from predators, with survival increasing with increasing availability of quality refuge sites. Absence of shelter within a post-fire site can negatively impact the probability of survival of individuals/species through higher predation rates due to higher detection rates as well as increased exposure to the elements. Management of this threat involves the provision of species-specific artificial shelter, such as artificial tunnels, at specified sites and knowledge of where these would be naturally located within the environment (e.g. proximity to water sources, number of entrances).
2. Decreasing the availability of species-specific food items (e.g. vegetation, invertebrates) within the post-fire environment which can reduce the probability of survival (due to starvation) and reproductive potential of individuals. Management of this threat involves the provision of species-specific supplementary food items, such as native grasses, fungi and invertebrates, at specified sites, but this action may have unanticipated impacts such as increasing the threat of novel competition with introduced rodent species (*Mus musculus* and *Rattus* spp.). This threat/action combination is very complex and is associated with numerous knowledge gaps which need to be addressed before management actions can be implemented including identification of key food resources for species, nutritional requirements and best-practice supplementation methods.
3. Decreasing the reproductive capabilities of individuals through the disruption or depletion of species-specific reproductive requirements (e.g. availability of nesting sites, nesting substrates, and food items) within the post-fire environment. Management of this threat involves the provision of artificial nest sites specific to the reproductive requirements of small mammals, such as artificial tunnels or dens, at specified sites. However, key knowledge gaps need to be addressed before artificial nest sites can be provided such as gaining a comprehensive understanding of the reproductive needs of different species to ensure all critical species-specific habitat characteristics are replicated (e.g. depth underground, climatic conditions within burrows).
4. Decreasing the suitability of the habitat to individuals/species through the increased presence of weeds and decreased presence of native vegetation, including coarse debris, which individuals rely on for food and shelter. Reduced habitat suitability negatively impacts the survival and reproduction of individuals/species. Management of this threat involves revegetation of sites with appropriate native species as well as weed removal to enhance the suitability and quality of the habitat for the target species. This is a complex threat with larger models in place (e.g. SMP actions, vegetation models).
5. Increasing novel competition for critical resources between introduced rodent species (e.g. *Mus musculus* and *Rattus* spp.) and native rodent species within the post-fire environment, reducing the amount of food available. Management of this threat involves the provision of species-specific supplementary food items, such as native grasses, fungi and invertebrates, at specified sites, but this is also expected to further increase novel competition with introduced rodent species.

6. Increasing predator impact habitats within the post-fire environment amplifying predation pressure on small mammals due to attraction of predators to the area and loss of ground cover as protection. Management of this threat involves the implementation of appropriate predator control, such as baiting, shooting and trapping, at specified sites to relieve predation pressures on target species. This is a complex threat with larger models in place (e.g. SMP fox models) or which are required.
7. Increasing feral herbivore impact habitats (e.g. reduced plant biomass, trampling of soil, soil erosion) within the post-fire environment decreasing the suitability of the habitat to small mammals. Management of this threat involves the implementation of appropriate feral herbivore control measures, such as fencing, contraception and culling, at sites to maintain and enhance suitable habitat for native rodents and small marsupials and to reduce the impacts of inappropriate fire. This is a complex threat with larger models in place or which are required.

Fire is a complex concept and is an ongoing active field of research, thus there is a degree of uncertainty in how to model all of the relevant processes within the system. Consequently, the 'inappropriate fire' causal model consists of 30 nodes and 46 edges (linking relationships) despite efforts to simplify the complex processes inherent in the system into broad variables to reduce the number of nodes. Of the linking relationships between nodes, we classified 17 relationships as relatively well understood and fixed (strength and direction are considered known) between the best- and worst-case scenarios (e.g. inappropriate fire has a strongly negative impact on habitat suitability for small mammals; coded light green in the matrix). Twenty relationships are considered variable with the magnitude of the correlation influenced primarily by this model (coded yellow in the matrix), while nine relationships are considered variable with the magnitude of the correlation influenced by other existing model frameworks or requiring larger models (coded light orange in the matrix). These variable relationships were assigned maximum and minimum values to describe the best- and worst-case scenarios encompassing the uncertainties in the model due to: 1) the large range of possible values for each model relationship evident among the different species of native rodents and small marsupials (to reflect the species-specific nature of the relationships as values need to be estimated for individual species to be useful); 2) site-specific characteristics influencing the probability of success of the identified management actions (e.g. prescribed burns work better in some landscapes than others); and 3) current knowledge gaps.

Below is a combined best- and worst-case scenario for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

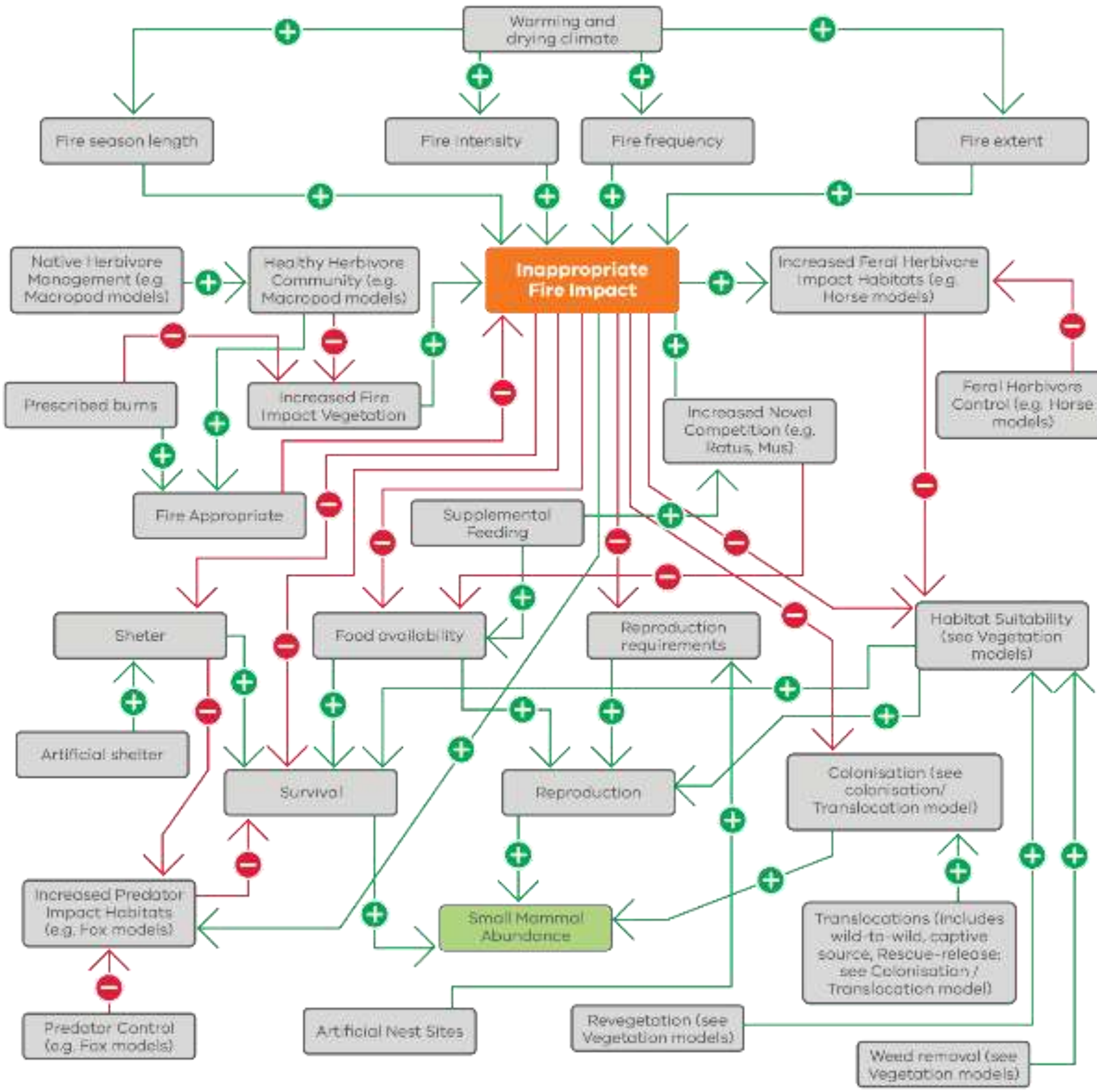

Figure 154. Best- and worst-case scenario casual model for impact of inappropriate fire on small mammal abundance. Diagram detail does not allow for visual representation of differences between best and worst relationships in this case. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Weed removal	Habitat suitability	0.189
1	Artificial shelter	Shelter	0.189
1	Translocation	Colonisation	0.189
1	Artificial nest sites	Reproduction requirements	0.189
1	Feral herbivore control	Increased feral herbivore impact habitats	0.189
1	Native herbivore management	Habitat suitability	0.189
7	Prescribed burns	Increased fire impact vegetation	0.184
7	Prescribed burns	Fire appropriate	0.184
9	Inappropriate fire impact	Colonisation	0.005
9	Inappropriate fire impact	Reproduction requirements	0.005
9	Increased feral herbivore impact habitats	Habitat suitability	0.005
9	Colonisation	Small mammal abundance	0.005
9	Supplemental feeding	Increased novel competition	0.005
9	Increased novel competition	Food availability	0.005
9	Increased fire impact vegetation	Inappropriate fire impact	0.005
9	Fire Appropriate	Inappropriate fire impact	0.005
9	Fire season length	Inappropriate fire impact	0.005
9	Fire intensity	Inappropriate fire impact	0.005
9	Fire frequency	Inappropriate fire impact	0.005
9	Fire extent	Inappropriate fire impact	0.005
21	Inappropriate fire impact	Survival	0.003
21	Inappropriate fire impact	Increased novel competition	0.003
21	Increased predator impact habitats	Survival	0.003
21	Revegetation	Habitat suitability	0.003
21	Healthy herbivore community	Increased fire impact vegetation	0.003
21	Healthy herbivore community	Fire appropriate	0.003
21	Supplemental feeding	Food availability	0.003

Figure 155. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for inappropriate fire on small mammal abundance.

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The highest ranked links were between weed removal and habitat suitability, artificial shelter and shelter, translocation and colonisation, artificial nest sites and reproduction requirements, feral herbivore control and increased feral herbivore impact habitats, native herbivore management and habitat suitability (reduction in uncertainty 0.189), and prescribed burns increased fire impact vegetation and fire appropriateness (reduction in uncertainty of 0.184. These might be good candidates for research projects, as they represent the highest reduction in uncertainty.

II. Impact of translocations on small mammal abundance and genetic diversity

The second problem-response scenario determined for native rodents and small marsupials in Victoria is 'translocation' and gene mixing. We constructed a 'translocation' causal model consisting of one key objective with one component, two threats, three external modifiers, 14 processes and 14 management actions. The key objective of the model is to increase the abundance and genetic diversity of small mammals at specified sites through increased colonisation either through natural colonisation or management translocations. The primary goal of our model was to consider the factors effecting both natural dispersal/immigration and translocations as both can lead to increased colonisation through different management actions. Several key questions are addressed by this model and highlight current knowledge gaps. These include:

- What factors influence the connectivity and natural dispersal between populations?
- What factors influence successful colonisation once arriving at a site whether through natural dispersal or translocation?
- How is fragmented habitat influencing populations, their demography, and their movements throughout the landscape?
- What are the genetic risks to populations/species?
- What are the species-specific best-practice methods to successfully release individuals into the wild from other wild sites, following rescue and release (e.g. after bushfires) or from a captive source?
- What are the ecological requirements of the target species and are these going to be fulfilled at the proposed translocation site?

Small mammal abundance and genetic diversity at a site is impacted by both colonisation and emigration. Here we model colonisation (separated into translocations and natural immigration); a further model is required to model the processes and actions associated with emigration. Colonisation, as well as small mammal abundance and genetic diversity at a site, are directly impacted by a multitude of threats including predation, competition, disease, climate change and habitat loss/fragmentation. These known threats which can cause population declines need to be removed, or appropriately controlled, from a site before attempting a translocation (and which have been addressed in other key SMP models). The impact of inappropriate fire is identified as the key threatening process within this model under the assumption that all other threats have been addressed (see the 'inappropriate fire' causal model for further detail).

There are three translocation strategies which can be implemented as management actions to increase small mammal abundance and genetic diversity at a site:

1. Rescue and release (emergency collection, housing and release in response to bushfires);
2. Wild-to-wild translocations (to novel sites or to supplement existing populations); and
3. Captive source translocations (released individuals sourced from a captive population)

All three translocation strategies are associated with biosecurity risk management (i.e. the potential of introducing disease and/or parasites to the translocated site/existing population). Transmission of novel diseases/parasites have the potential to reduce small mammal abundance and genetic diversity at a site.

To maximise the probability of translocation success, comprehensive knowledge of the target species' ecology and behaviour is required prior to translocation. Success is also dependent on the:

- Local adaptation of source animals (e.g. fitness is negatively affected in new environments due to limited genetic diversity)
- Health condition of source animals (e.g. animals undergo health checks prior to translocation and only healthy, fit individuals free from disease and parasites are translocated)
- Captive habituation of the source individuals for captive source translocations (e.g. behaviour responses such as loss of predator recognition and avoidance behaviours and the inability to locate/utilise appropriate food/shelter sources)

Colonisation via natural immigration is dependent on several processes within the environment, with management actions identified to overcome these processes including:

- Abundance of the target species at neighbouring sites (high abundance increases the likelihood of colonisation) which is influenced by various habitat characteristics including the availability of food/shelter resources, absence of predators/competitors, and habitat quality. Management involves improving the habitat quality of neighbouring sites (this requires the development of a model).
- Distance between occupied sites. Increased distance between unoccupied and occupied sites decreases the likelihood of movement of animals between the sites, especially where the matrix habitat is in poor condition. Management involves increasing the number of occupied sites within the

environment such as through wild-to-wild or captive source translocations. This requires knowledge about why species are absent from locations (i.e. are habitat conditions inappropriate or are individuals not able to transverse the matrix naturally due to distance/matrix quality).

- Survival of the target species within the matrix which is influenced by habitat quality and various threats including inappropriate fire, predators, and competitors. Rodent species can also modify their reproductive strategies (e.g. reproduce at lower body weights) in response to a decrease in the population number due to fire which can increase immigration to recolonise the site. Management involves improving the quality of the habitat matrix and habitat corridor revegetation with appropriate native species to enable movement of target species throughout the matrix habitat. This is a complex threat with larger models in place (e.g. SMP actions, vegetation models) or which are required.

The three processes mentioned above all impact the connectivity of the matrix habitat which directly impacts the probability of an individual/species colonising a site. Increased survival within the matrix and abundance at neighbouring sites both positively impact the connectivity of the matrix habitat, while decreased distance between occupied sites negatively impacts the connectivity of the matrix habitat.

Inappropriate fire has numerous direct effects on several habitat characteristics and community interactions which impact colonisation and thus the success of natural colonisations and translocations, with seven management actions identified to overcome these threatening processes to promote colonisation including:

- Decreasing the suitability of the habitat to individuals/species through the increased presence of weeds and decreased presence of native vegetation, including coarse debris, which individuals rely on for food and shelter. Therefore, burnt areas do not provide sufficient resources to support recolonisation by new individuals. Management of this threat involves revegetation of sites with appropriate native species as well as weed removal to enhance the suitability and quality of the habitat for target species. This is a complex threat with larger models in place (e.g. SMP actions, vegetation models) or which are required.

- Decreasing the availability of species-specific shelter. Absence of shelter within a post-fire site can negatively impact the probability of colonisation of the site as individuals are exposed to the physical environment and predators and can instead increase emigration from the site. Management of this threat involves the provision of species-specific artificial shelter, such as artificial tunnels, at specified sites and knowledge of where these would be naturally located within the environment (e.g. proximity to water sources, number of entrances).

- Decreasing the reproductive requirements of species (e.g. nesting sites, nesting substrates, food items) at a post-fire site. Management of this threat involves the provision of artificial nest sites specific to the reproductive requirements of small mammals, such as artificial tunnels or dens, at specified sites. However, before artificial nest sites can be provided, key knowledge gaps need to be addressed such as gaining a comprehensive understanding of the reproductive needs of different species to ensure all critical species-specific habitat characteristics are replicated (e.g. depth underground, climatic conditions within burrows).

- Decreasing the availability of species-specific food items (e.g. vegetation, invertebrates) at a post-fire site which can reduce the probability of colonisation of target species due to reduced probability of survival (i.e. due to starvation). The decrease in food availability can also result in increased novel competition for critical resources with introduced rodent species (e.g. *Mus musculus* and *Rattus* spp.), further reducing the amount of food available at a burnt site. Provision of species-specific supplementary food items, such as native grasses, fungi and invertebrates, at specified sites can increase the availability of food at the site level and therefore colonisation potential, but may have unanticipated impacts such as further increasing the threat of novel competition with introduced rodent species. This threat/action combination is very complex and is associated with numerous knowledge gaps which need to be addressed before management actions can be implemented including identification of key food resources for species, nutritional requirements and best-practice supplementation methods.

- Decreasing the connectivity of the matrix habitat through depletion of critical resources (i.e. species-specific food items and shelter) thus reducing habitat quality and increasing the distance between suitable sites that individuals need to traverse.

- Decreasing the probability of survival of individuals within the post-fire environment due to direct mortality or depletion of critical resources (i.e. species-specific food items and shelter).

- Increasing feral herbivore impact habitats (e.g. reduced plant biomass, trampling of soil, soil erosion) within the post-fire environment decreasing the suitability of the habitat thus reducing the survival of small mammals within the matrix habitat. Management of this threat involves the implementation of appropriate feral herbivore control measures, such as fencing, contraception and culling, at sites to maintain and enhance suitable habitat for native rodents and small marsupials and to reduce the impacts of inappropriate fire. This is a complex threat with larger models in place (e.g. SMP horse models) or which are required.
- Increasing predator impacts habitat within the post-fire environment amplifying predation pressure on small mammals due to attraction of predators to the area and loss of ground cover (shelter) as protection thus reducing the survival of small mammals within the matrix habitat. It is crucial that predators are controlled at the proposed site before translocation occurs. Management of this threat involves the implementation of appropriate predator control, such as baiting, shooting and trapping, at specified sites to relieve predation pressures on target species. This is a complex threat with larger models in place (e.g. SMP fox models) or which are required. The loss of shelter within the matrix can be managed through the provision of species-specific artificial shelter, such as artificial tunnels, to reduce predation pressures at specified sites by reducing detection rates.

The ‘translocation’ causal model consists of 35 nodes and 50 edges (linking relationships) despite efforts to simplify the complex processes inherent in the system into broad variables to reduce the number of nodes. Of the linking relationships between nodes, we classified 18 relationships as relatively well understood and fixed (strength and direction are considered known) between the best- and worst-case scenarios (e.g. availability of food at a site has a strongly positive impact on colonisation by small mammals; coded light green in the matrix). Twenty-seven relationships are considered variable with the magnitude of the correlation influenced primarily by this model (coded yellow in the matrix), while five relationships are considered variable with the magnitude of the correlation influenced by other existing model frameworks (coded light orange in the matrix). These variable relationships were assigned maximum and minimum values to describe the best- and worst-case scenarios encompassing the uncertainties in the model due to: 1) the large range of possible values for each model relationship evident among the different species of native rodents and small marsupials (to reflect the species-specific nature of the relationships as values need to be estimated for individual species to be useful); 2) site-specific characteristics influencing the probability of success of the identified management actions (e.g. prescribed burns work better in some landscapes than others); and 3) current knowledge gaps.

Below is a combined best- and worst-case scenario for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

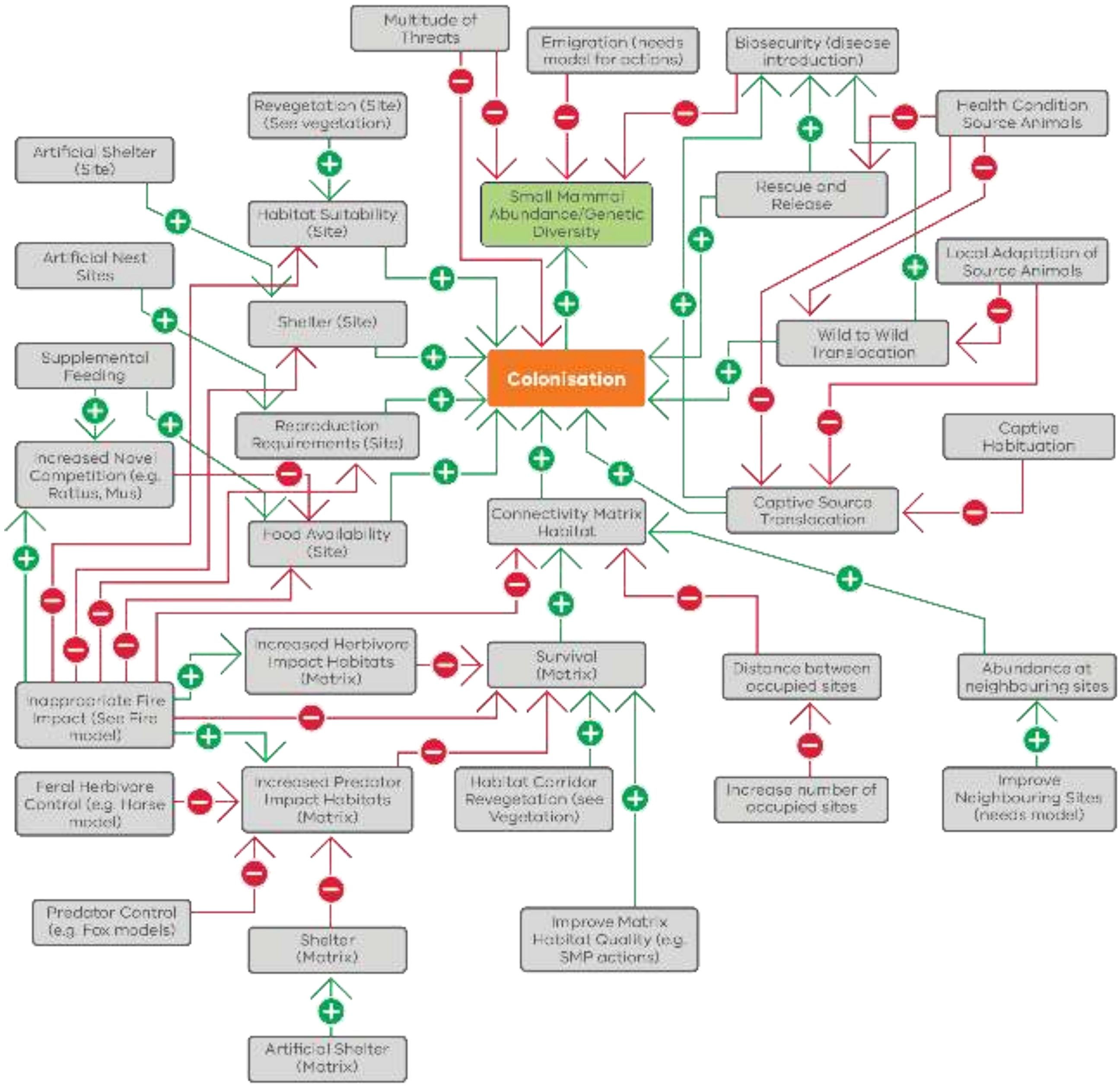

Figure 156. Best- and worst-case scenario casual model for impact of translocations on small mammal abundance and genetic diversity. Diagram detail does not allow for visual representation of differences between best and worst relationships in this case. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Revegetation site	Food availability site	0.217
1	Artificial nest sites	Reproduction requirements site	0.217
1	Artificial shelter site	Shelter site	0.217
1	Artificial shelter matrix	Shelter matrix	0.217
5	Emigration needs model for actions	Small mammal abundance genetic diversity	0.201
6	Multitude of threats	Colonisation	0.008
6	Abundance at neighbouring sites	Connectivity of matrix Habitat	0.008
6	Biosecurity disease introduction	Small mammal abundance genetic diversity	0.008
9	Rescue and release	Biosecurity disease introduction	0.006
9	Wild to wild translocation	Biosecurity disease introduction	0.006
9	Captive source translocation	Biosecurity disease introduction	0.006
9	Non local adaptation of source animals	Captive source translocation	0.006
9	Captive habituation	Captive source translocation	0.006
9	Rescue and release	Colonisation	0.006
9	Wild to wild translocation	Colonisation	0.006
9	Captive source translocation	Colonisation	0.006
9	Inappropriate fire impact	Connectivity of matrix Habitat	0.006
9	Supplemental feeding	Food availability site	0.006
9	Increased novel competition	Food availability site	0.006
9	Supplemental feeding	Increased novel competition	0.006
9	Colonisation	Small mammal abundance genetic diversity	0.006
9	Multitude of threats	Small mammal abundance genetic diversity	0.006
23	Improve neighbouring sites	Abundance at neighbouring Sites	0.003
23	Inappropriate fire impact	Increased novel competition	0.003
23	Increased herbivore impact habitats matrix	Survival matrix	0.003
23	Increased predator impact habitats matrix	Survival matrix	0.003
23	Non local adaptation of source animals	Wild to wild translocation	0.003

Figure 157. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for translocations on small mammal abundance and genetic diversity.

The highest ranked links were between revegetation sites and food availability sites, artificial nest sites and reproduction requirements sites, artificial shelter sites and shelter sites, artificial shelter matrix and shelter matrix (reduction in uncertainty of 0.217), and emigration needs model for actions and small mammal abundance genetic diversity (reduction in uncertainty of 0.201). These might be good candidates for research projects, as they represent the highest reduction in uncertainty.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 146 and 147) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Broad-Toothed Rat (BTR; *Mastacomys fuscus mordicus*)

The 2019/20 bushfires burned a large proportion of the most abundant populations of the BTR, in Victoria. Broad-Toothed Rat occur naturally in patches of optimal habitat (e.g. grassy meadows, bogs, fens) embedded in a matrix of forested habitats. The resilience of the species in the state is affected by numerous continuing threats, not least of which are feral herbivores, feral predators, and climate change.

Number of experts: 9

Locations: Eastern Alpine National Park

Current population in Victoria: The scenario asked experts to consider BTR persistence at site Bog 230 in Eastern Alpine National Park that was consumed by the bushfires. In this exercise, BTR persistence at Bog 230 is dependent on actions at three sites: (1) the focal burnt site, Bog 230; (2) the nearest unburnt site with BTRs, Bog 231; and (3) the intervening matrix habitat between the two sites.

The analysis is intended to compare the value of actions that would increase *in situ* survival in Bog 230 with investment in actions that would increase natural immigration to Bog 230 through metapopulation connectivity. It is intended to capture input on where actions should be focused to achieve these complementary goals and where there is uncertainty in this decision making.

Bog 230 is an area with 95% of BTR habitat burnt in 2020. The severe fire scar extends 1 km or more in all directions. Prior to fire, this area (~ 5 ha) was prime habitat with an abundant population size. There are signs of isolated BTR (fresh scats) after fire on margin in habitat patches (<0.01 ha each). Feral herbivores (horse, deer, rabbit) and predators (fox, cat) are common in the area. The nearest unburnt and known BTR occupied site is around 2 km away (Bog 231).

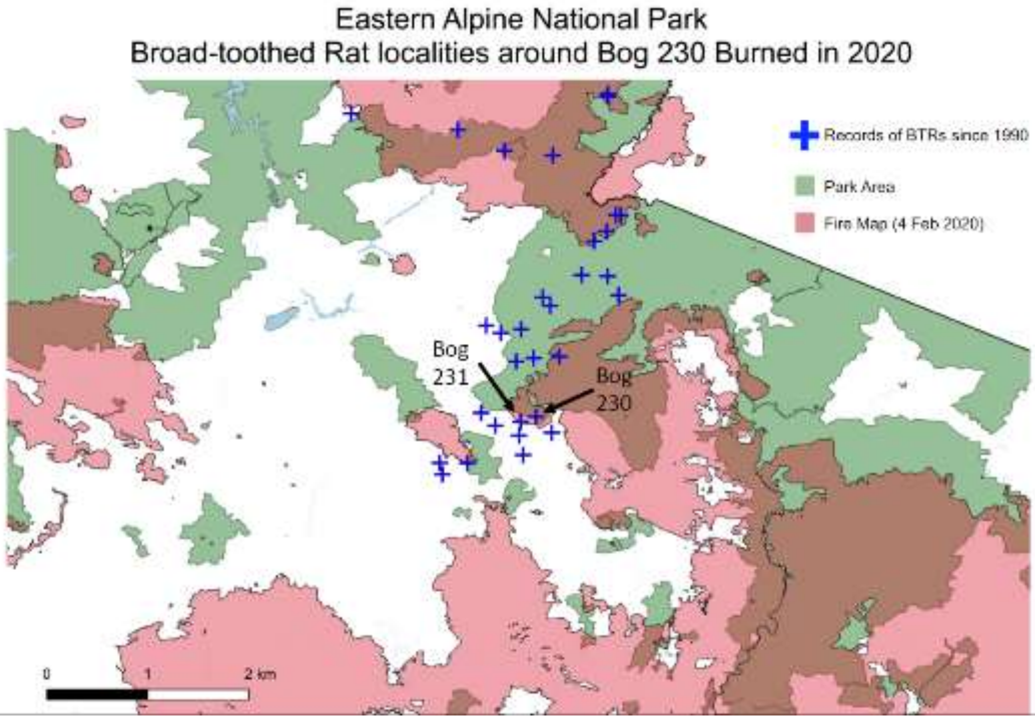

Figure 158. Locations for Broad-Toothed Rat actions

#	Actions:	For simplicity, the actions focus on the combined impacts of feral herbivores (horse, deer, rabbit) and feral predators (fox, cat), which are common and major threats in the area. For this model, natural immigration is assumed to be more efficient than *ex situ* management actions (e.g. translocations). However, that is not meant to preclude the value of these actions to the species at a larger scale or under different circumstances.
	No action	As described.
1	Feral Control (Fence)	Assumed to include removal.
2	Feral Control (Removal)	In addition to landscape level removal actions under SMP (feral combines herbivore and predators).
3	Feral Control (Artificial Refuge)	Refuge provided while habitat regenerating after fire e.g. bushfire shelter.

Based on expert assessment the benefit of each action at each location for this species is as follows:

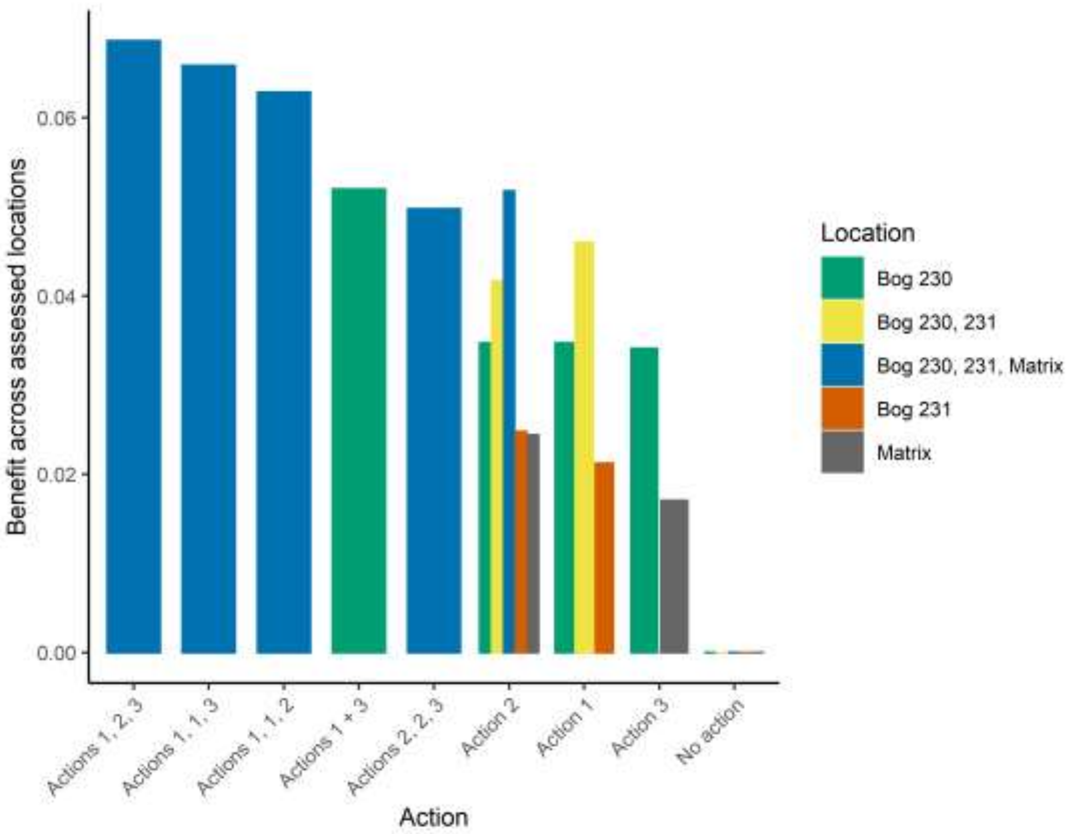

Figure 159. Benefit of each action/location combination to the Broad-Toothed Rat overall persistence probability across all assessed locations.

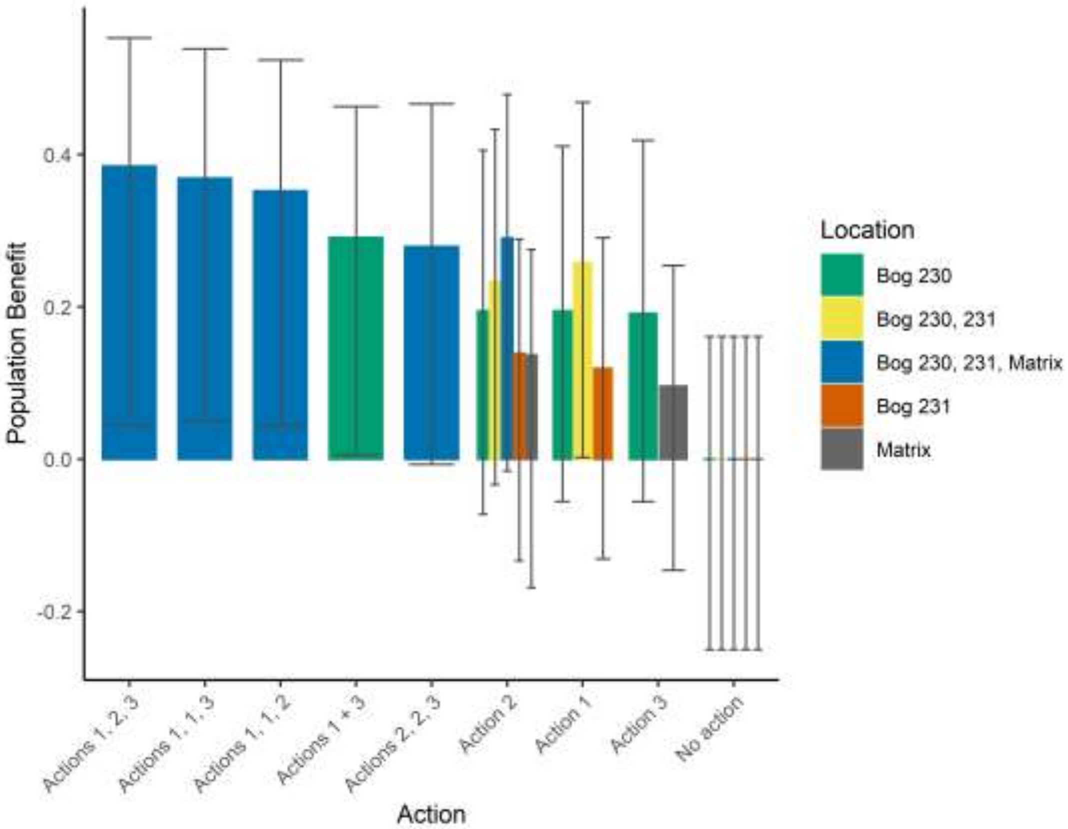

Figure 160. Mean change in Broad-Toothed Rat probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Actions for this species focus on feral herbivore and predator control, by one or a combination of three different mechanisms. Across both sites and the matrix, there is a relatively high benefit to any combination of these control. Where single actions are considered, fencing (with assumed removal) is preferred in Bog 230 + 231, while removal is preferred in Bog 231, the matrix and Bog 230 + 231 + matrix. Bog 230 shows little preference between individual actions.

Species: Fat-Tailed Dunnart (FTD; *Sminthopsis crassicaudata*)

Like for most native rodents and small marsupials, estimating population trends for FTD is challenging as the majority of populations are known only through infrequent, incidental detections. The species lives across a wide range of habitats and are generally considered widespread and least concern for extinction. However, estimating population trends are challenging (as for other small dasyurids) because there are few overlapping records through time.

Fat-Tailed Dunnart are unique among small mammals because of their use of mixed landscapes, which may be important to maintaining connectivity and their persistence across the landscape. The parks and reserves of the Wimmera wheatbelt are embedded in an agricultural matrix shifting from pasture to increasing levels of cropping. Our intent for this assessment was to investigate the effectiveness of various management actions proposed to increase connectivity and therefore persistence of fat-tailed dunnart in a small isolated reserve, Kiata FFR. This assessment was designed to elicit opinions about actions dependent on private landowners (i.e. compliance or incentives) and those actions focused on management intervention.

The agricultural matrix connects populations. Within the agricultural matrix, the conversion of pasture to broadacre cropping drives decline of coarse debris, paddock trees, shelter belts, and invertebrates, threatening the persistence of FTD. These changes to the agricultural matrix impact many species through loss of useable habitat and reduced connectivity between parks and reserves.

Fat-tailed dunnarts and other small dasyurids are also threatened by feral cats, the impact of which are compounded by the changing agricultural landscape and decline in shelter.

Number of experts: 8

Locations: Kiata Flora and Fauna Reserve, north of Little Desert National Park.

Current population in Victoria: Location reflects the connectivity of numerous reserves and parks embedded in an agricultural matrix that may be central to the health and resilience of FTD. In this exercise, local persistence of FTD is dependent on actions taken under different land use scenarios in the intervening agricultural matrix: (1) maintenance of current levels of pasture and cropping; (2) conversion to all broadacre cropping, (3) conversion to all perennial or native pasture.

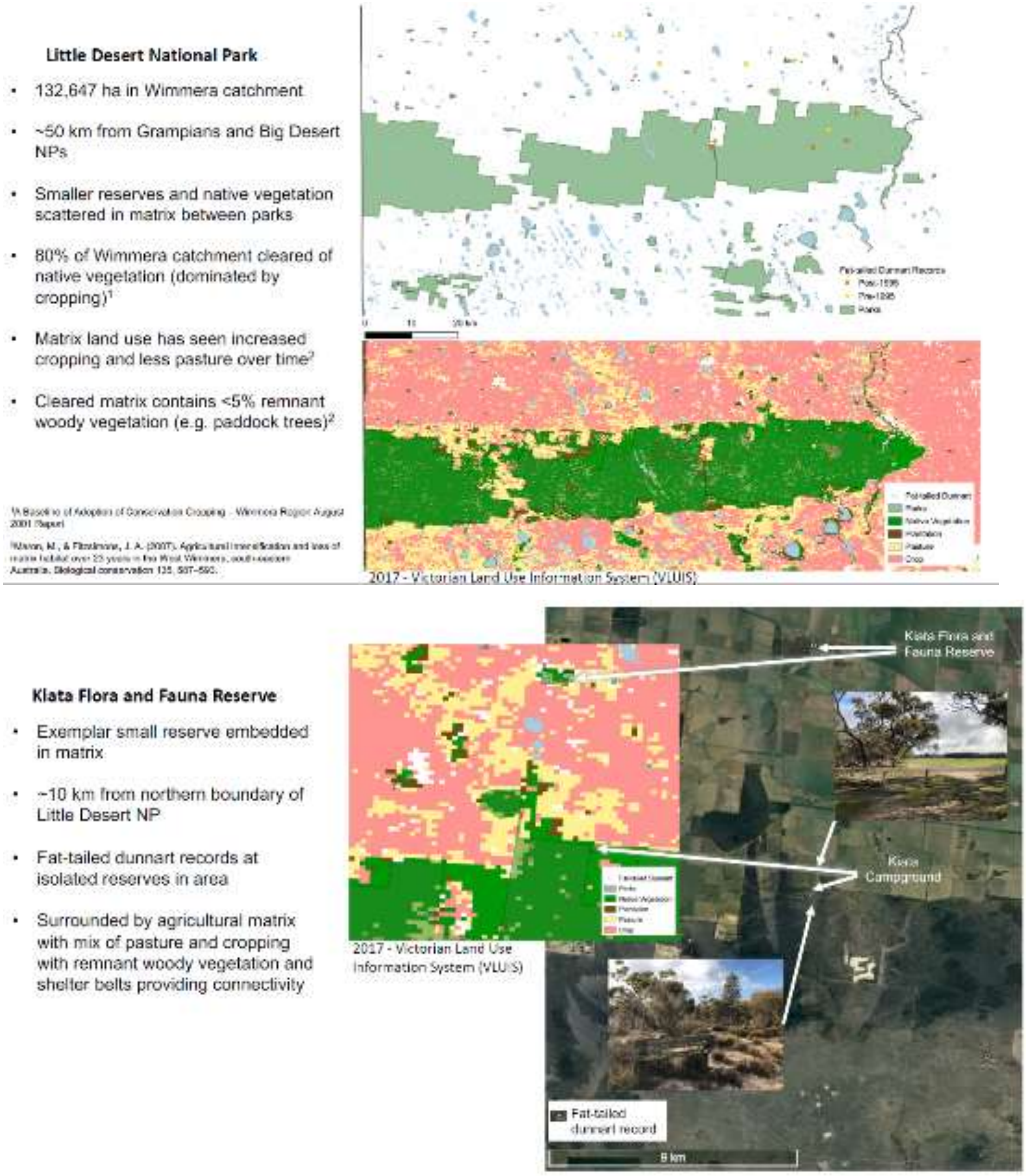

Figure 161. Location and description of Little Desert National Park (described matrix) and Kiata Flora and Fauna Reserve (site for Fat-tailed Dunnart actions).

#	Actions:	
	No action	As described.
1	Increased compliance	Around collection of firewood and retaining paddock trees.
2	Financial incentives	For remnant vegetation on private land through management agreements or covenants.
3	Roadside vegetation management and restoration	Creation of shelter belts.
4	Coarse debris supplementation	Reuse trees removed for roadwork.

Based on expert assessment the benefit of each action at each location for this species is as follows:

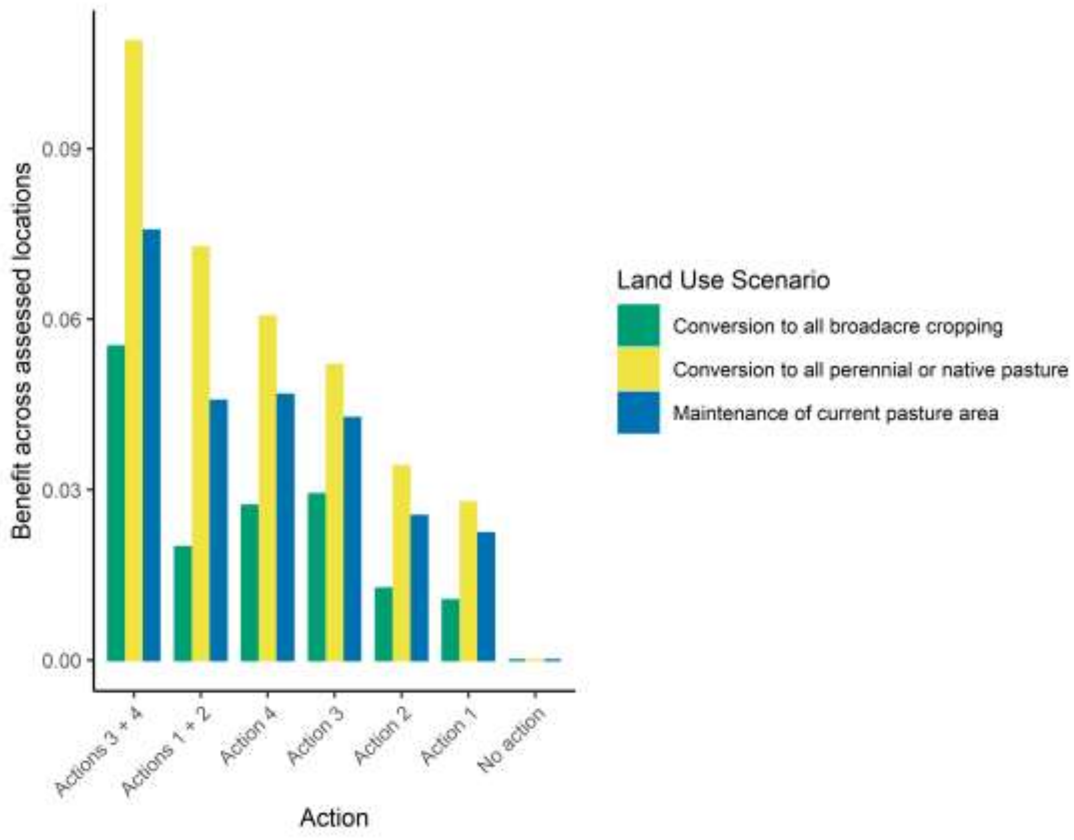

Figure 162. Benefit of each action/location combination to the Fat-Tailed Dunnart overall persistence probability across all assessed locations.

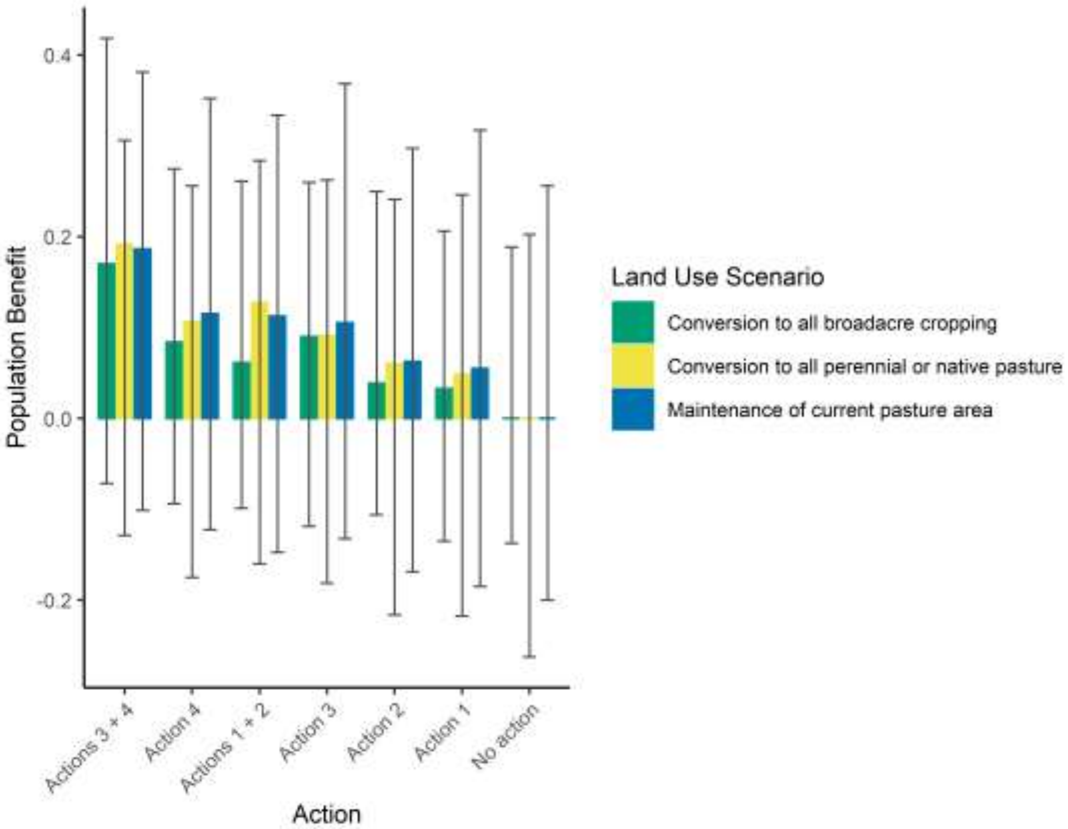

Figure 163. Mean change in Fat-Tailed Dunnart probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

These results demonstrate that differing land use scenarios in the future will influence the benefit of current management actions for the FTD. Conversion to perennial or native pasture results in greater probability of persistence, particularly when considered across all locations. However, experts estimated that under each condition, worst case scenario still results in a disbenefit to the species from each action. In terms of action, coarse debris supplementation (action 4) and roadside vegetation management and restoration (action 3) are considered more potentially beneficial than financial incentives (actions 2) and increased compliance around firewood and trees.

Species: New Holland Mouse (NHM; *Pseudomys novaehollandiae*)

New Holland Mouse, are distributed from southern Queensland to Tasmania. Since 1980, the species has disappeared from the majority of localities where they were recorded in Victoria and Tasmania, likely due to urbanisation and other land use development.

The rapid decline of NHM and their disappearance from many localities across the state are both concerning and puzzling. Understanding the causes of their decline and the appropriate actions to preserve the species are challenged by their cryptic nature and a lack of understanding of the optimal habitat requirements and population ecology of the species. The species is known to fluctuate dramatically in abundance within and among years driven in part by a complicated and poorly understood relationship with fire and habitat succession. One proposed solution has been the development of an insurance population in the fenced reserve at the Royal Botanic Garden (RBG) Cranbourne, which is near an area where the NHM were once recorded. Our SNA was designed to elicit responses about the probability of persistence on the Yanakie Isthmus of Wilson's Promontory National Park with or without a Cranbourne population. The Yanakie Isthmus is now the westernmost population of the species in Australia and maintains a small, isolated population of uncertain but probably low abundance. In addition to supplementation from RBG Cranbourne to Yanakie

Isthmus, we considered the actions of apply fire and intensive feral predator control, two actions that are considered central to the specific management of the species.

Number of experts: 4

Locations: Yanakie Isthmus, Wilsons Promontory NP (WPNP) and Royal Botanic Garden, Cranbourne (RBGC). These locations represent a translocation event.

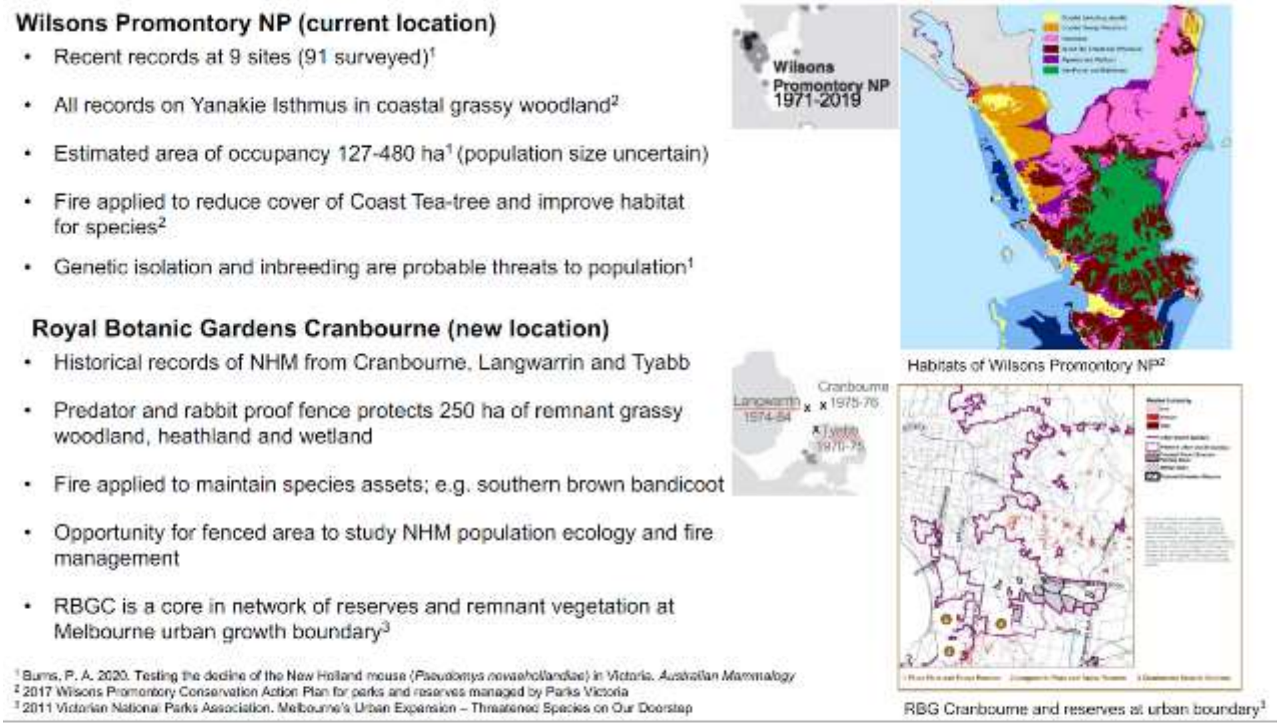

Figure 164. Location details provided to experts for New Holland Mouse elicitation.

#	Actions:	
	No action	As described.
1	Apply fire	Fire applied experimentally to determine optimum for NHM.
2	Intensive feral predator control	At translocated sites.
4 3	Translocation (with supplementation)	From WPNP to RBG Cranbourne (2-5 years) and supplementation from RBGC to WPNP (10-50 years). Translocations conducted according to best practice for release in semi-wild enclosure to be determined by veterinary staff and institutions (e.g. food/shelter supplementation, soft-release). Translocated animals to be sourced during peak abundance (i.e. Autumn) and numbers to be determined on the ground (e.g. <10% of captured animals).

Based on expert assessment the benefit of each action at each location for this species is as follows:

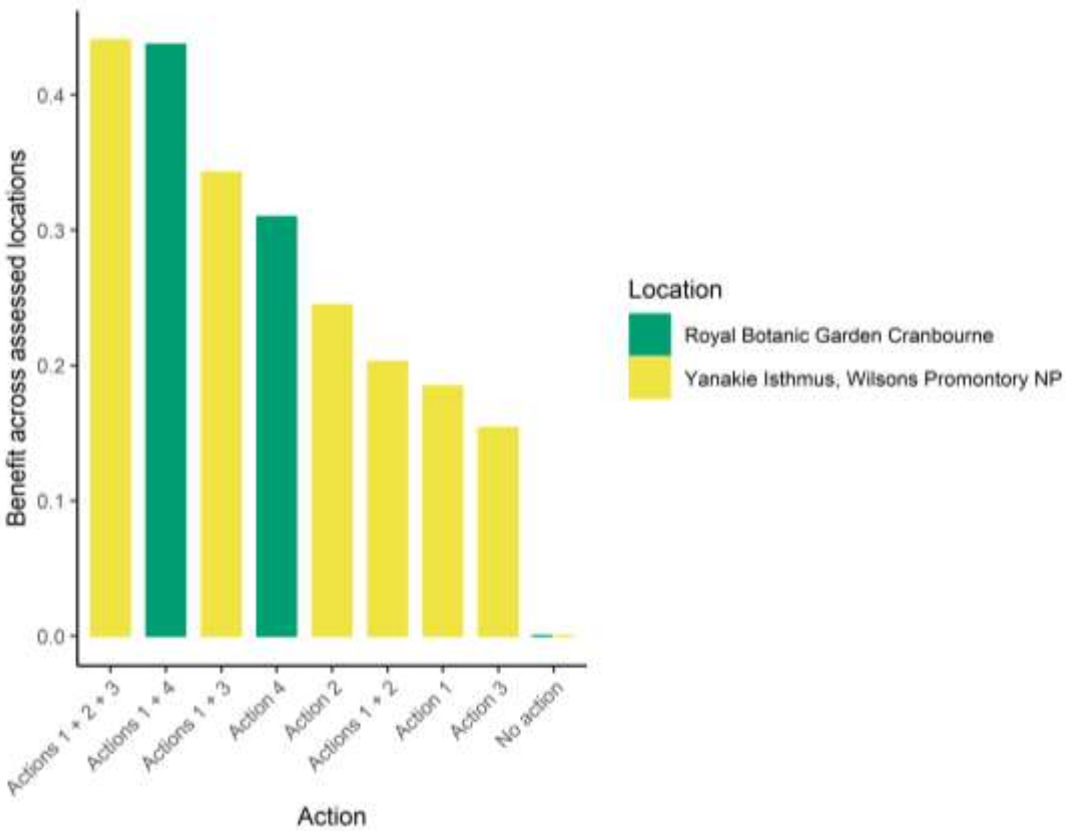

Figure 165. Benefit of each action/location combination to the New Holland Mouse overall persistence probability across all assessed locations.

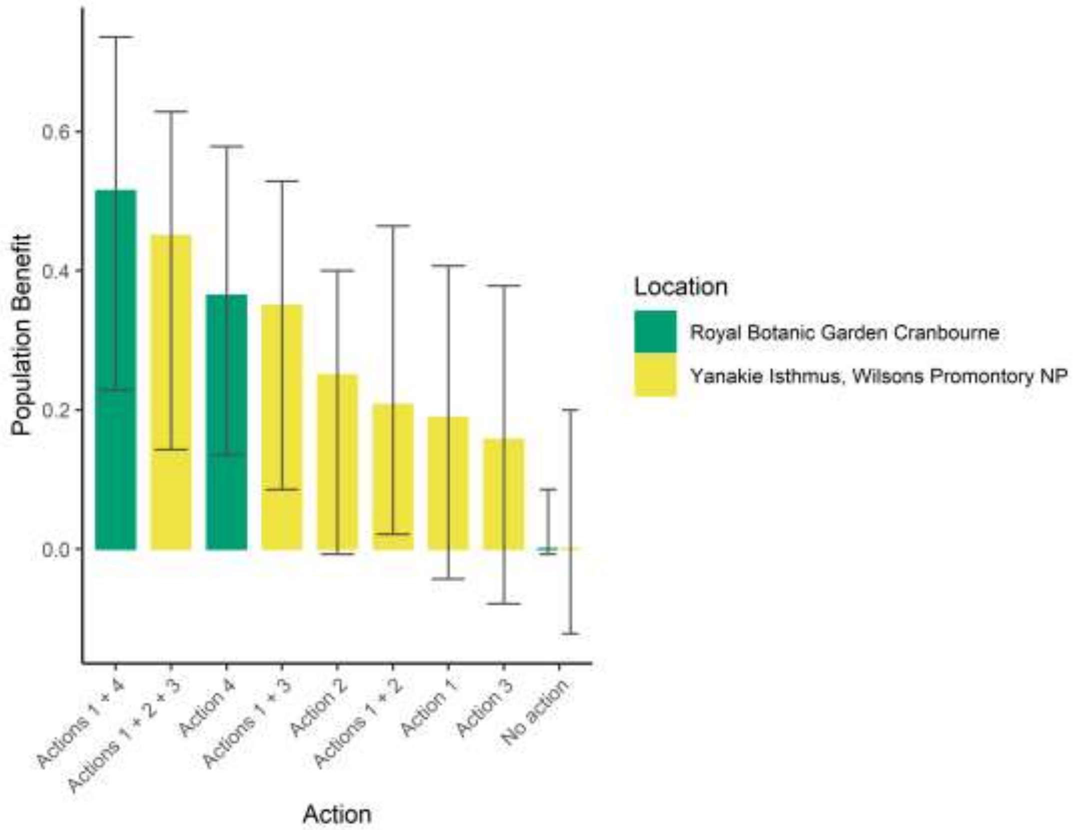

Figure 166. Mean change in New Holland Mouse probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

When considering the current location in Wilsons Promontory National Park, intensive feral predator control is predicted to be the most beneficial single action for New Holland Mouse persistence, however combinations of actions (other than the application of optimal fire with predator control) score higher. Optimal fire application provides a substantial boost to benefit of translocation to Royal Botanic Garden Cranbourne.

Species: Ningaui (*Ningaui yvonneae*)

Mallee Ningaui (Ningaui), are patchily distributed with relatively localised movements across south western NSW, north western Victoria, South Australia and southern Western Australia.

The abundance of Ningaui is strongly correlated with the presence of hummock grass (spinifex; *Triodia* spp.) which provide shelter and foraging requirements. Ningaui are considered least concern for extinction, however, estimating population trends are challenging (as for other small dasyurids) because there are few overlapping records through time with the majority of populations known through infrequent, incidental detections.

The persistence of Ningaui in Victoria is threatened by repeated fires which can cause local extinction (especially if refuge areas from which recolonisation can occur are not preserved), habitat clearing (particularly of spinifex and leaf litter reducing suitable habitat and connectivity between habitat patches), domestic stock and feral herbivores through heavy grazing and trampling of habitat and food resources, and feral predators (the impact of which are compounded by decline in spinifex shelter from other threats).

Number of experts: 4

Locations: Murray-Sunset National Park and Annuello Flora and Fauna Reserve

Current population in Victoria: The Mallee is a heavily fire managed landscape with many species, like the Mallee Ningaui, depending on long unburnt areas (>15 years) to regenerate the hummock/spinifex grass habitat they require. Several planned burns in the last 10 years have been along park and reserve boundaries or dissected parks and reserves. This assessment was designed to elicit how planned burns effect connectivity for Mallee Ningaui and their local persistence. Respondents were asked to estimate persistence in the large Murray-Sunset NP and the smaller Annuello FFR, which is connected to Murray-Sunset NP by a narrow corridor of habitat. Management actions were selected that could increase connectivity through burns.

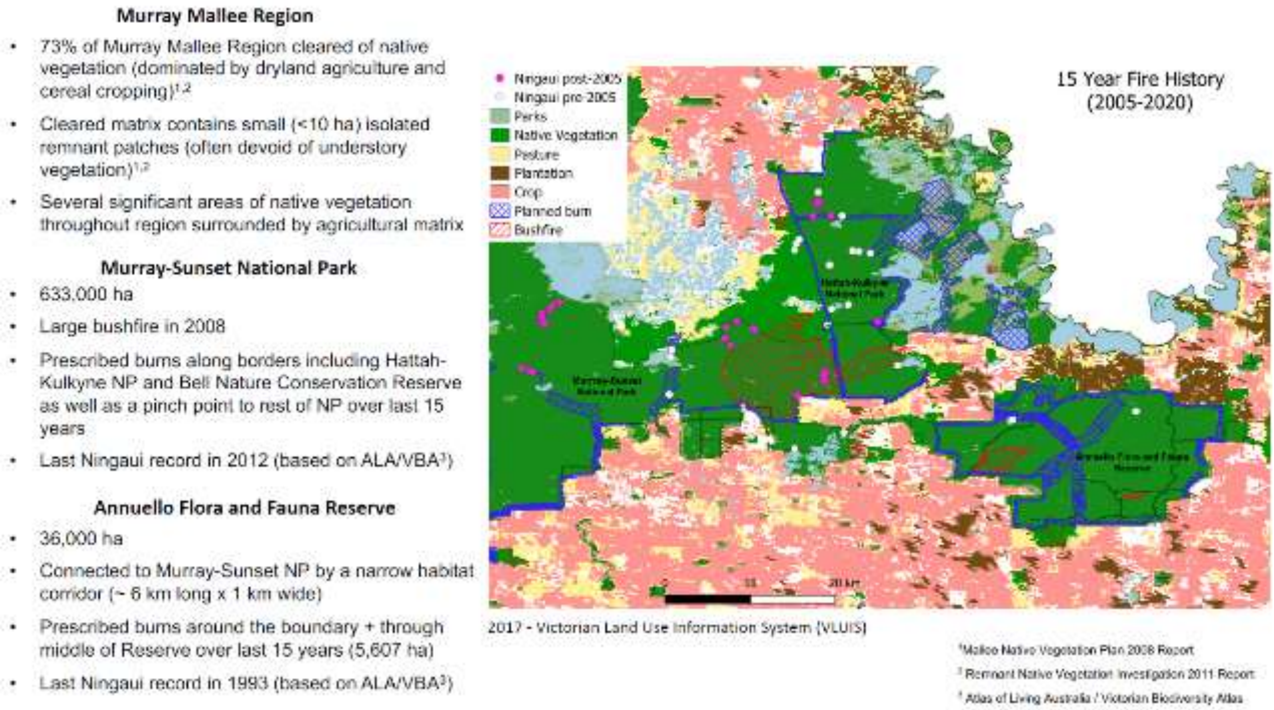

Figure 167. Location details provided by taxon lead to experts for Ningaui elicitation

#	Actions:	
	No action	As described.
1	Provide artificial refuges	In fire scars.
2	Exclude feral herbivores	Fencing and restore habitat in corridors between reserves.

Experts were asked to consider each of the above actions for each location under these fire scenarios:

1. Maintenance of current levels of prescribed burns (<15 years fire frequency)
2. Cessation of prescribed burns around park boundaries (>30 years fire frequency)
3. Maintenance of current levels of strategic burns
4. Cessation of strategic break burns around park boundaries

Based on expert assessment the benefit of each action at each location for this species is as follows:

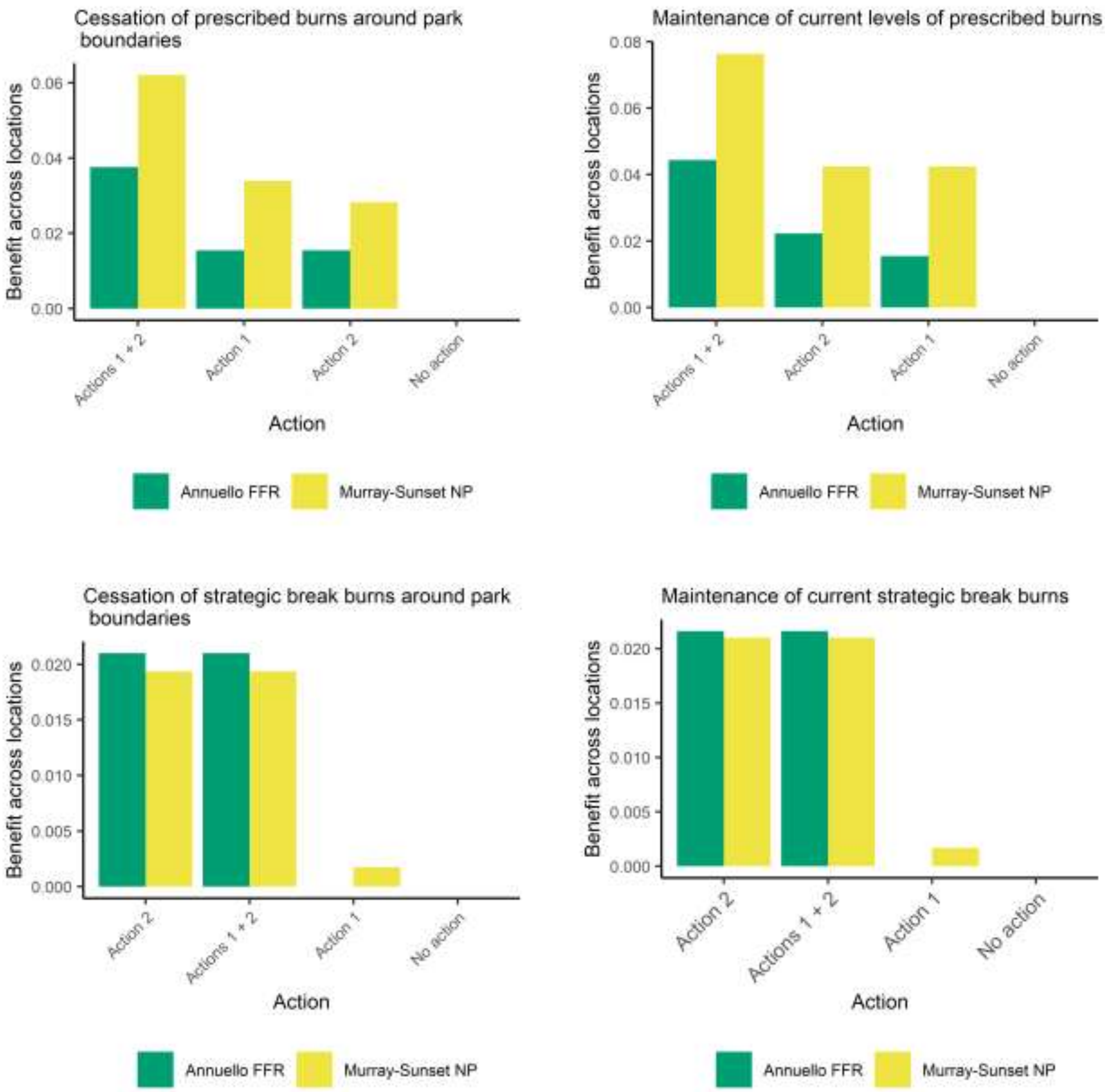

Figure 168. Benefit of each action/location combination to the Ningaui overall persistence probability across all assessed locations.

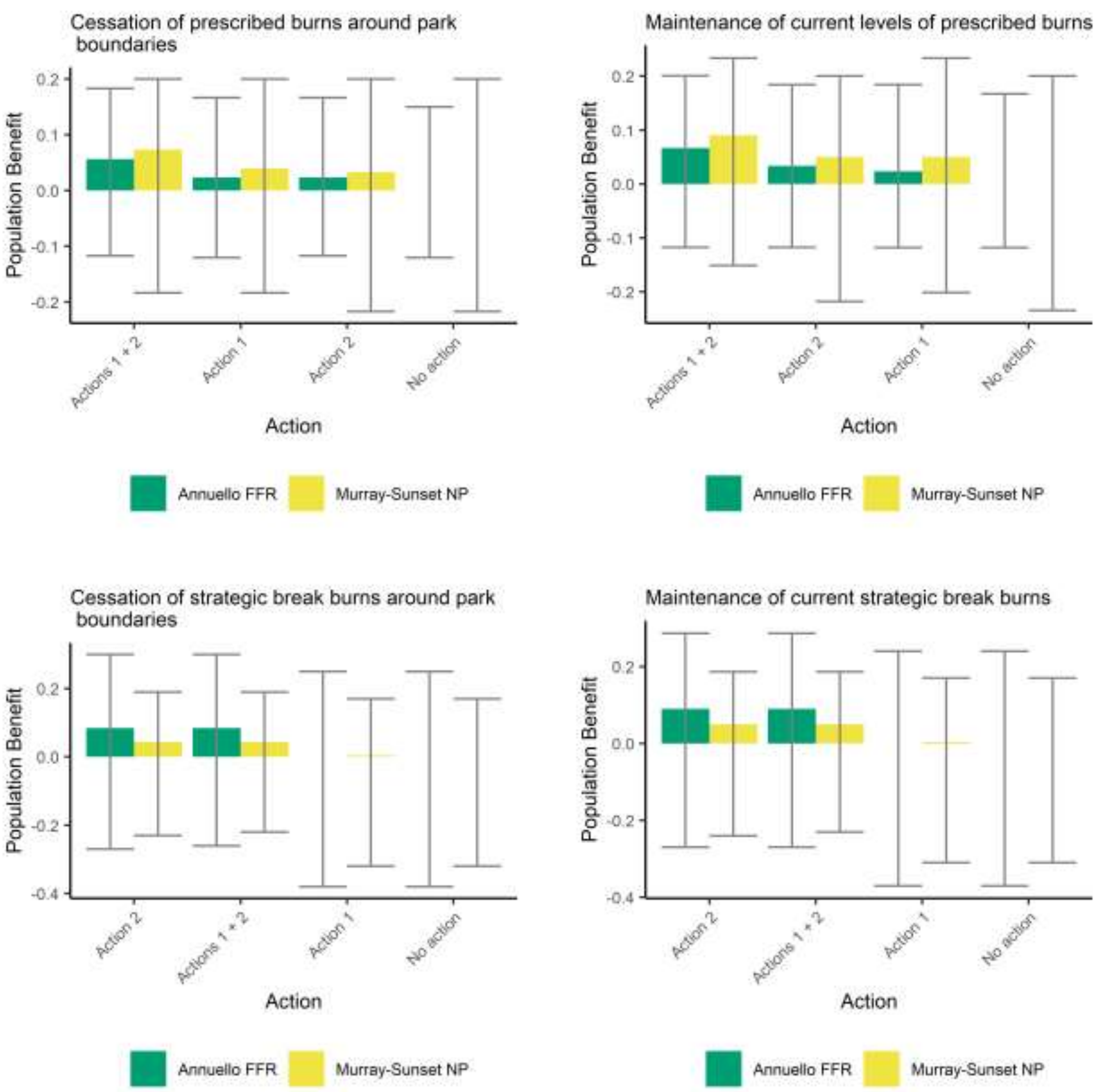

Figure 169. Mean change in Ningaui probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

These results demonstrate how fire management strategies interact with other management actions to produce different outcomes for species persistence. When prescribed burns cease around park boundaries, the provision of artificial refuges is the most beneficial single action. In each other scenario, exclusion of feral herbivores through fencing and habitat corridors provides the greatest single benefit at both sites.

Species: Smoky Mouse (*Pseudomys fumeus*)

Smoky mouse in the Grampians National Park persist in two areas (Mt William Range and Victoria Range) that are each <10 km^2. The key variables that limit them to these areas and the threats to their persistence are not well understood. In the Victoria Range, smoky mouse have been consistently detected along a small number drainages since 2012 despite a severe fire in 2013 burning through all known sites. Their use of habitat outside these drainages has not been demonstrated in the Victoria Range, although it is considered optimal habitat elsewhere in their range. This assessment was designed to elicit expert opinion on the effectiveness of management actions given underlying knowledge scenarios such as whether or not optimal sites are known (i.e. in the drainages) and/or low survival events are predictable. We considered a range of plausible actions in the Victoria Range focused on responding to periods of low survival (e.g. drought, fire, or seasonal) including intensive feral predator control, non-native rodent control, food supplementation, rescue and release, and population supplementation.

The 2019/20 bushfires burned ~40% of suitable habitat for Smoky Mouse, in Victoria. Populations in the Grampians are isolated from all other populations by almost 400 km and have been impacted by recent large bushfires including the 2013 Victoria Valley fire that burned all known populations in the Victoria Range. Smoky Mouse are known to co-occur with non-native rodents (*Rattus*, *Mus*), especially after fire.

The resilience of the species in the state is affected by numerous continuing threats, not least of which are feral herbivores, feral predators (extensive feral predator control programs in place in Grampians), fire, drought and climate change, but many threats and their impacts are poorly understood.

Number of experts: 8

Locations: Victoria Range, Grampians NP

Current population in Victoria: Mt William site is dominated by subalpine snow gum (elevation to 1200m). Less than 10 individuals are known to persist there from any site since 2012 (from >100 in 1980).

Victoria Range is dominated by wet forest drainages (elevation to 700m). Some sites are known to have over 10 individuals.

The key variables that limit them to these areas and the threats to their persistence are not well understood. In the Victoria Range, Smoky Mouse have been consistently detected along a small number drainages since 2012 despite the severe fire in 2013 burning through all known sites and impacts of the Millennium Drought (2012-2020). Their use of habitat outside these drainages has not been demonstrated in the Victoria Range, although it is considered optimal habitat elsewhere in their range.

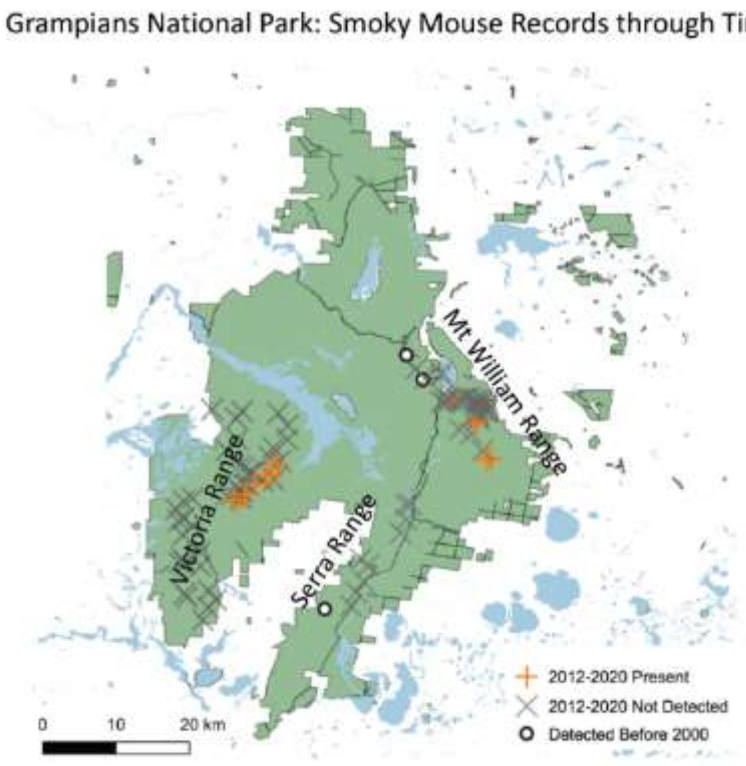

Figure 170. Grampians National Park location details

#	Actions:	
	No action	As described.
1	Increased feral control	Focused during/following periods of low survival in situ (e.g. fire, drought, seasonal).
2	Non-native rodent control	Focused during/following periods of low survival in situ (e.g. fire, drought, seasonal).
3	Population and supplementation	Ex situ, either from captive sources or translocation from other Victorian populations.
4	Rescue and release	Ex situ, including veterinary treatment and/or holding until low survival period passes.
5	Supplemental food and water	Focused during/following periods of low survival in situ (e.g. fire, drought, seasonal).

Experts were asked to consider each of the above actions under each biological knowledge scenarios:

1. Optimal sites identified, periods of low survival detectable/predictable
2. Optimal sites unidentified, periods of low survival detectable/predictable
3. Optimal sites unidentified, periods of low survival undetectable/unpredictable

Based on expert assessment the benefit of each action at each location for this species is as follows:

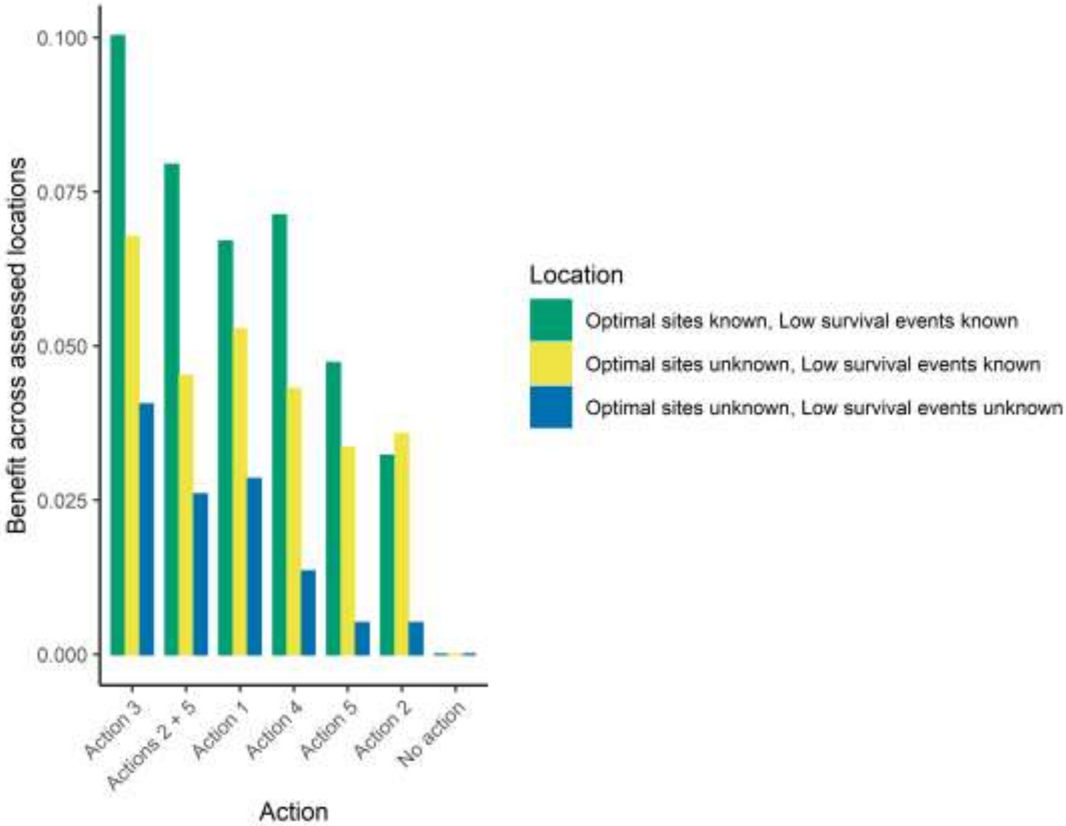

Figure 171. Benefit of each action/location combination to the Smoky Mouse overall persistence probability across all assessed locations.

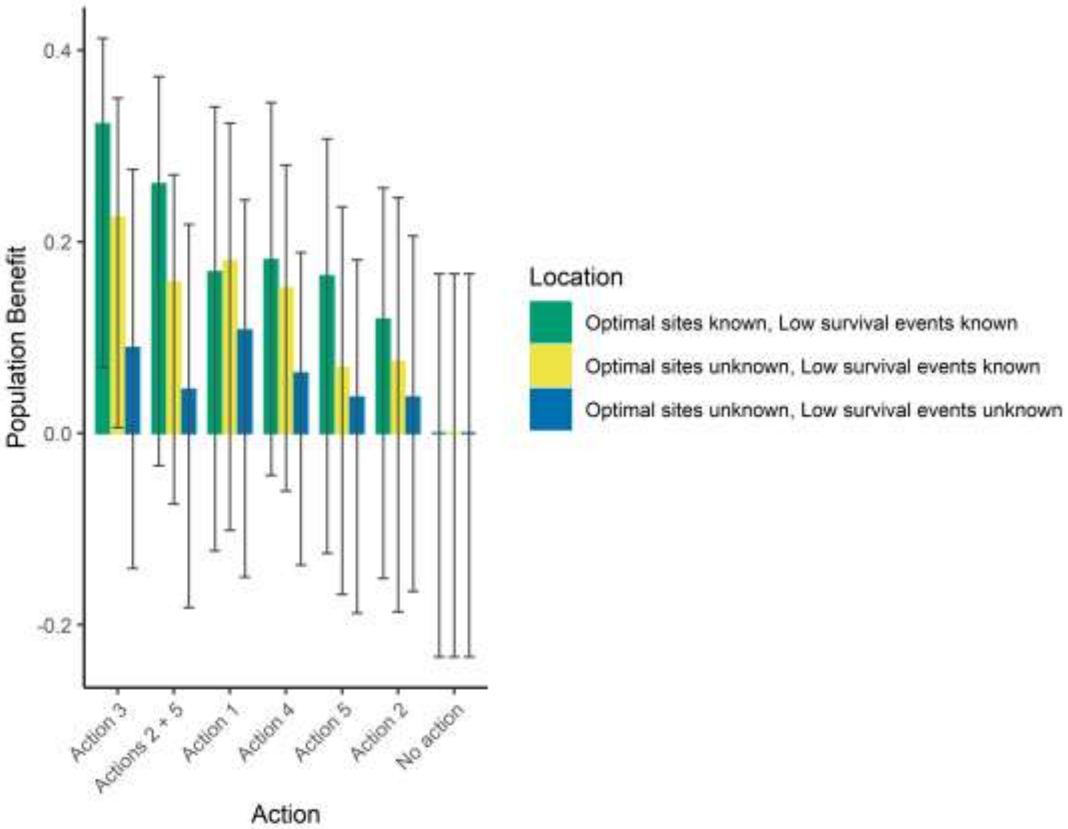

Figure 172. Mean change in Smoky Mouse probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

These results demonstrate that benefit to a species is maximised with increased knowledge. Where optimal sites and the periods of low survival are predictable, less uncertainty exists about the outcome of an action, and the most appropriate and effective action can then be selected for the site and enacted at the right time. In this case, supplementation of a population from captive sources or translocation from other Victorian populations was ranked most beneficial for Smoky Mouse.

Reptiles

Introduction

Assessments were completed for seven species. Actions chosen are based on a large suite of assumptions (described) including accurate understanding of species numbers, population, and genetic structure. Typically, the actions suggested require years of preparation and research to ensure quality and effectiveness. This work may help provide additional justification for such activities.

Key knowledge gaps

I. Habitat loss and degradation for Alpine Water Skink and Alpine Bog Skink in alpine and subalpine bogs, wet heath, and peatlands on the Bogong High Plains and eastern alps of Victoria.

The following model explores the major contributors to habitat loss and degradation, which is known to be a major threat for two high-risk lizards: the Alpine Water Skink and Alpine Bog Skink.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

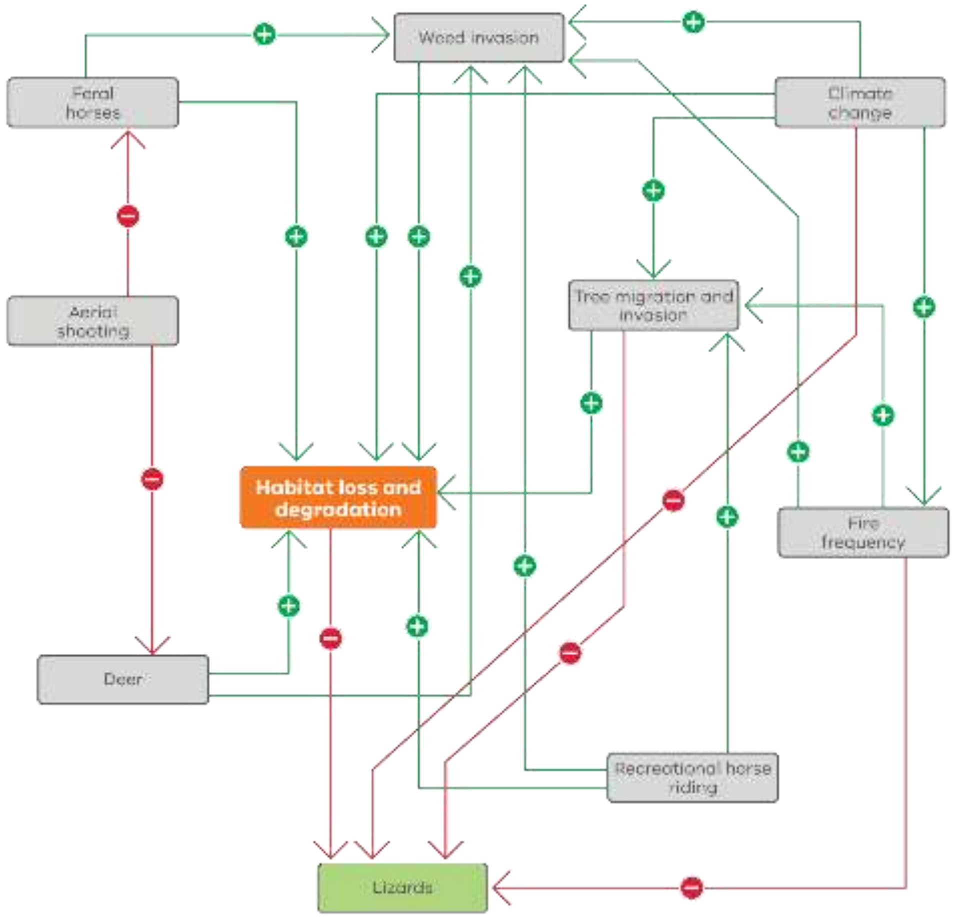

Figure 173. Best case scenario casual model for habitat loss and degradation for Alpine Water Skink and Alpine Bog Skink in alpine and subalpine bogs, wet heath and peatlands on the Bogong High Plains and eastern alps of Victoria. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

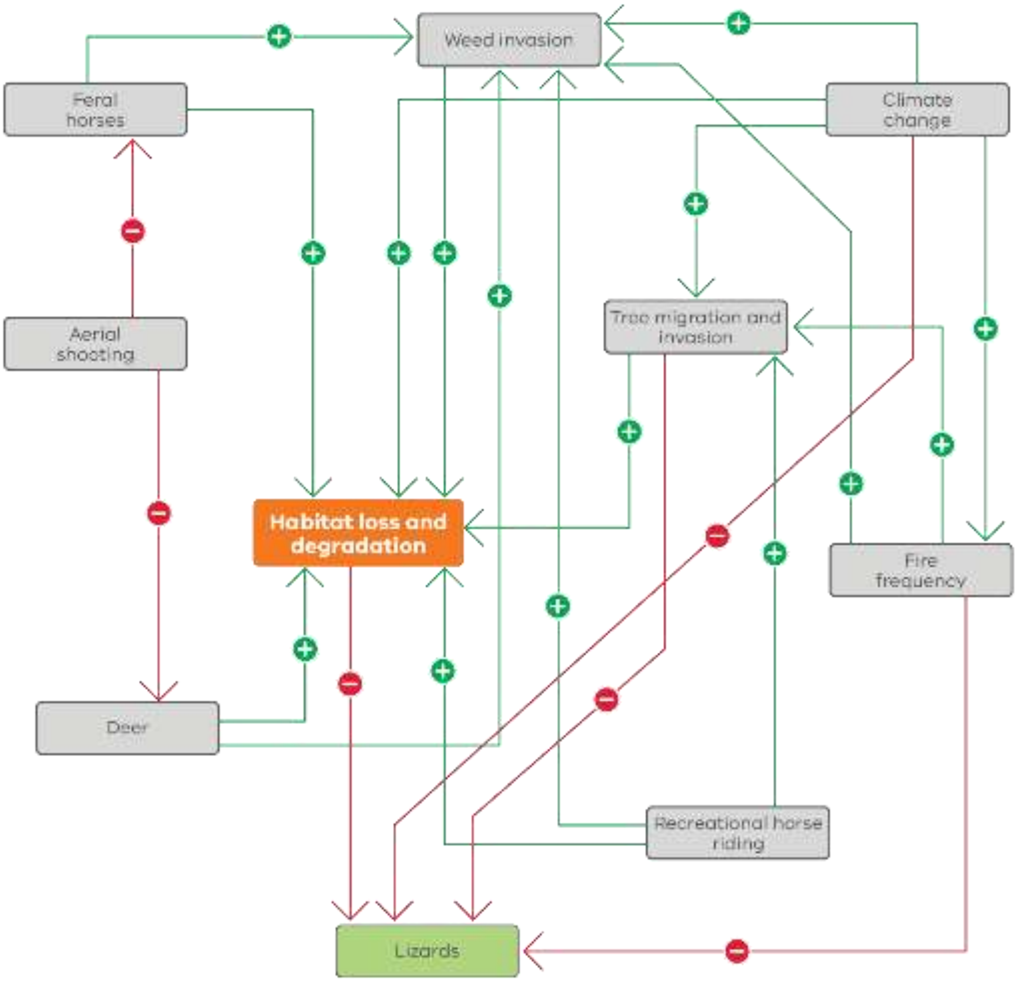

Figure 174. Worst case scenario casual model for habitat loss and degradation for Alpine Water Skink and Alpine Bog Skink in alpine and subalpine bogs, wet heath and peatlands on the Bogong High Plains and eastern alps of Victoria. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	Knowledge gap	Proportional reduction
1	The influence of Feral horses on Weed invasion	0.08
1	The influence of Weed invasion on Habitat loss and degradation	0.08
1	The influence of Habitat loss and degradation on Lizards	0.08
1	The influence of Fire frequency on Tree migration and invasion	0.08
1	The influence of Tree migration and invasion on Lizards	0.08
6	The influence of Aerial shooting on Feral horses	0.04
6	The influence of Aerial shooting on Deer	0.04
6	The influence of Feral horses on Habitat loss and degradation	0.04
6	The influence of Deer on Weed invasion	0.04
6	The influence of Deer on Habitat loss and degradation	0.04
6	The influence of Climate change on Weed invasion	0.04
6	The influence of Climate change on Habitat loss and degradation	0.04
6	The influence of Climate change on Lizards	0.04
6	The influence of Climate change on Fire frequency	0.04
6	The influence of Climate change on Tree migration and invasion	0.04
6	The influence of Fire frequency on Lizards	0.04
6	The influence of Tree migration and invasion on Habitat loss and degradation	0.04
6	The influence of Recreational horse riding on Weed invasion	0.04
6	The influence of Recreational horse riding on Habitat loss and degradation	0.04
6	The influence of Recreational horse riding on Tree migration and invasion	0.04

Figure 175. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for Habitat loss and degradation for Alpine Water Skink and Alpine Bog Skink in alpine and subalpine bogs, wet heath and peatlands on the Bogong High Plains and eastern alps of Victoria.

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. The top 5 actions might be good candidates for research projects, as they represent the equal highest reduction in uncertainty of 0.08.

II. Effect of gene mixing on reptile populations

The following model is a simple comparison of the effectiveness of gene mixing under three different conditions. The principals of this comparison extend beyond the reptiles considered in the following specific needs assessment and into other taxon.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

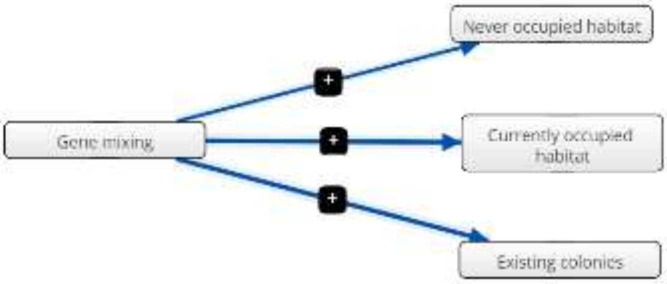

Figure 176. Best case scenario for effect of gene mixing on reptile populations. Blue arrows indicate a positive relationship between nodes.

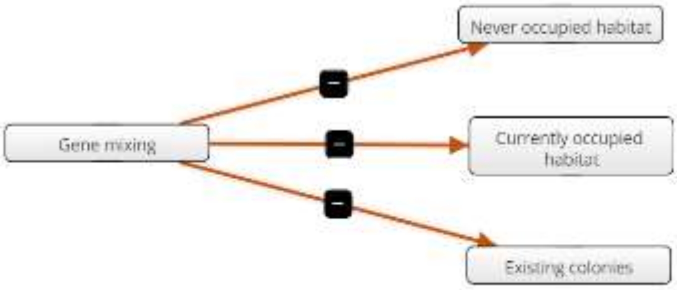

Figure 177. Worst case scenario for effect of gene mixing on reptile populations. Red arrows indicate a negative relationship between nodes.

Rank	Knowledge gap	Proportional reduction
1	Gene mixing into currently occupied habitat	0.357
1	Gene mixing into existing colonies	0.357
3	Gene mixing into currently never occupied habitat	0.286

Figure 178. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for effect of gene mixing on reptile populations.

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario. In this case, each action might be relatively even in their candidacy as research projects, with more investigation required.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 166 and 167) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species: Alpine She-oak Skink (*Cyclodomorphus praealtus*)

Number of experts: 5

Locations: Davies Plain and Mt Buffalo, a key unoccupied site and current population extent.

Current population in Victoria: Known to persist in 4 areas in Victoria: Bogong High Plains, Mt Hotham and surrounds, Dargo High Plains, and Wellington/Howitt Plains.

#	Actions:	
	No action	No management of wild populations.
1	Captive breeding	Breed 100 Alpine She-oak Skink (ASOS) in captivity. Insert a PIT tag into lizards when they reach a suitable size for tagging. Conduct thorough vet checks prior to release. Release ASOS at one Victorian location. Monitor released lizards as part of current mark-recapture program.
2	Gene mixing	Assuming results of current genetic analyses and future gene mixing trials in captivity indicate some populations would benefit from gene mixing, what would be the benefit of releasing gene mixed offspring into extant populations in Victoria?
3	Reintroduction to previously occupied but currently unoccupied suitable habitat	Assuming a detailed monitoring program indicates that previously occupied habitat is most probably currently unoccupied, donor populations have been determined, and all other factors indicate this is a worthwhile action (e.g., release propagule size determined, response if action fails, post-release monitoring program established, etc.), reintroduce ASOSs into previously occupied habitat.
4	Introductions to novel habitat	Novel habitat is defined as suitable ASOS habitat that's not currently occupied and has not been occupied previously. Assume that preliminary work (surveys, establishing monitoring sites, determination of numbers/age cohorts to be released, response if introduction fails, etc.) has been done.

Based on expert assessment the benefit of each action at each location for this species is as follows:

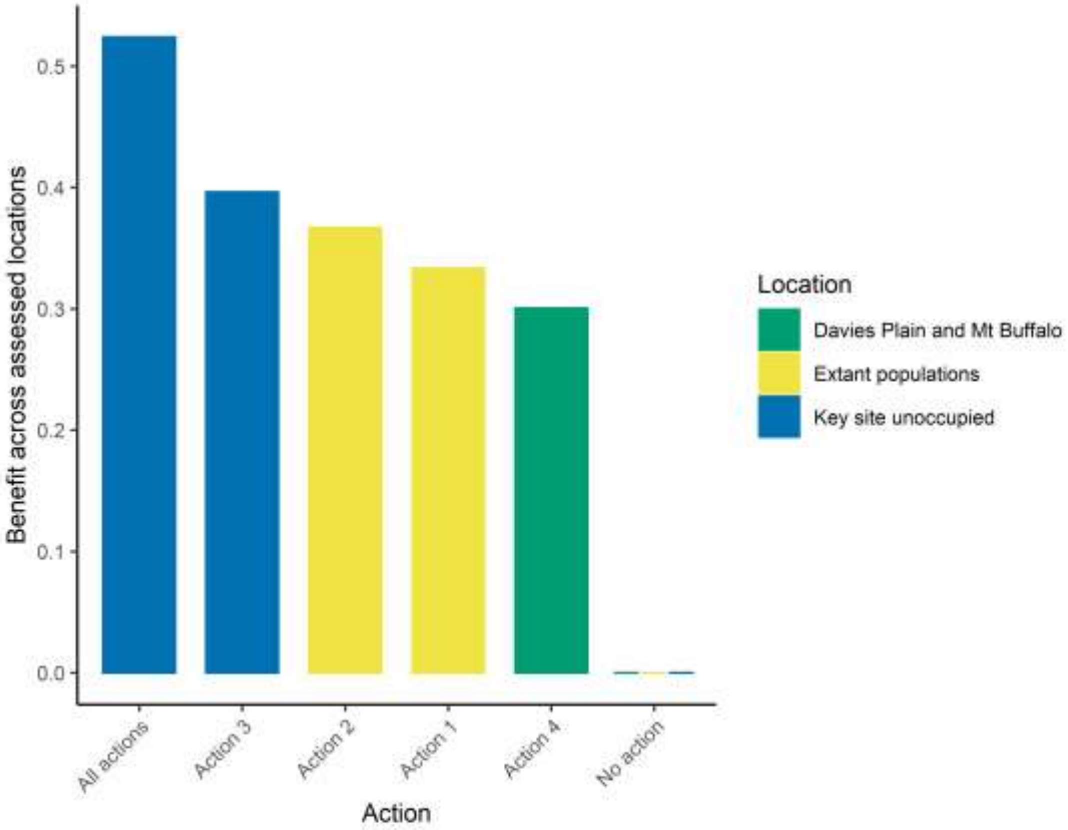

Figure 179. Benefit of each action/location combination to the Alpine She-Oak Skink overall persistence probability across all assessed locations.

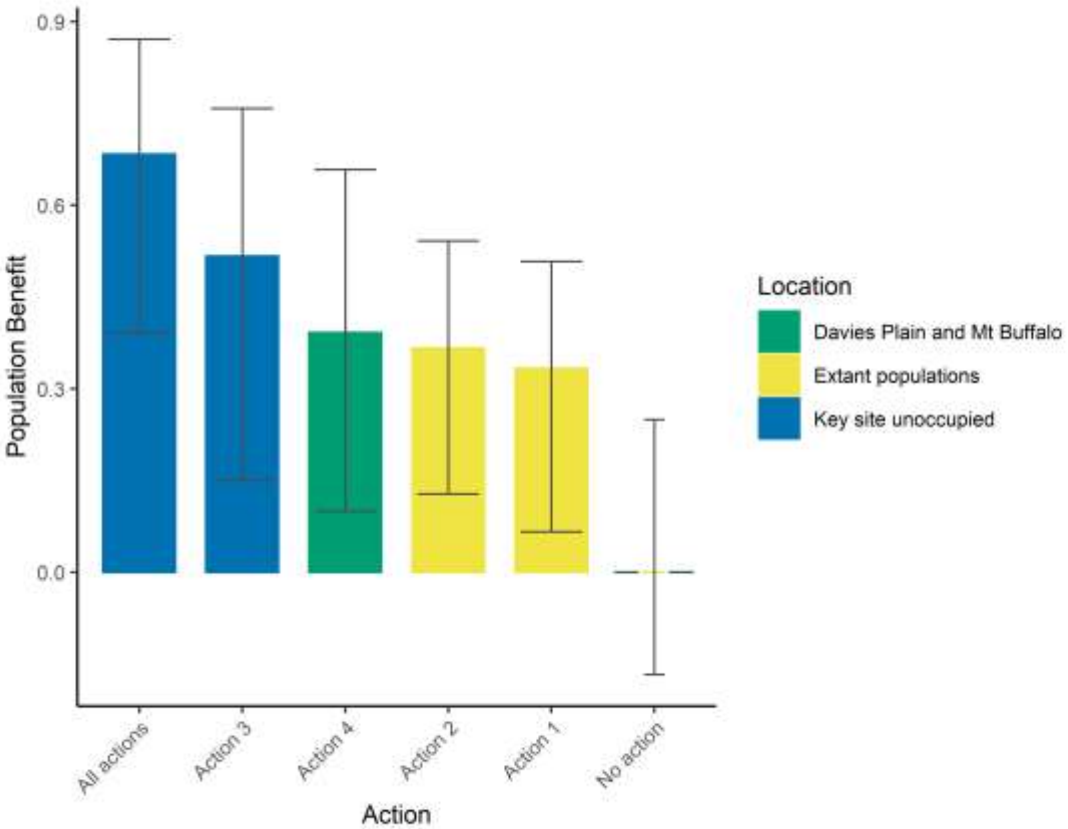

Figure 180. Mean change in Alpine She-Oak Skink probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Experts assessed the potential benefits for the proposed actions to be relatively high. Reintroduction into a currently unoccupied site may be very beneficial to the probability of persistence of the Alpine She-Oak Skink, particularly when paired with captive breeding and gene mixing. However, there is some variability in expert opinion as to how successful this may be. Previous and currently occupied sites are likely better options for management than novel sites, based on relative benefit across all locations.

Species: Guthega skink (*Liopholis guthega*)

Number of experts: 6

Locations: Bogong High Plains, Kosciuszko National Park, and current population extent.

Current population in Victoria: Known only from the Bogong High Plains in the Victorian Alps.

#	Actions:	
	No action	No management of wild populations.
1	Captive breeding	Assuming that funding for surveys is made available, and surveys locate extant populations, and those populations are determined to be able to cope with removal of sufficient numbers of individuals, establish a captive program from wild-caught snakes. The initial aim of the program is to develop husbandry protocols such that the species can be bred at will in captivity. Ideally have captive animals held by at least two zoos to spread risk. Aim to produce sufficient genetically healthy offspring to enable reintroduction to multiple sites on both private and public land.
2	Gene mixing	Assume results of current gene mixing experiments in the Skink Chalet at Healesville Sanctuary indicate that gene mixing will result in individuals that are more resilient to threatening processes. Carefully select individuals from donor and recipient colonies, use them to produce offspring in captivity (most likely a mix of Victorian and NSW Guthega Skink (GS)). After marking gene-mixed offspring (PIT tag when they reach a suitable size), release a suitable number of these offspring at recipient site(s) on the Bogong High Plains, and conduct careful monitoring as per the current mark-recapture program.
3	Reintroduction to previously occupied but currently unoccupied suitable habitat	Assuming a detailed monitoring program indicates that unoccupied habitat is most probably unoccupied, donor populations have been determined, and all other factors indicate this is a worthwhile action (e.g., release propagule size determined, response if action fails, post-release monitoring program established, etc.), reintroduce ASOSs into previously occupied habitat.
4	Introduction to currently unoccupied but suitable habitat	Find naturally occurring apparently suitable habitat within the known Victorian range of the GS that is currently unoccupied. Introduce suitable GS to this habitat. Monitor these introductions over appropriate timeframes.
5	Introductions to novel habitat	Novel habitat is defined as suitable GS habitat that's not currently occupied and has not been occupied previously. Assume that preliminary work (surveys, establishing monitoring sites, determination of numbers/age cohorts to be released, response if introduction fails, etc.) has been done.
6	Creation of new habitat	Assume that a reason has been found to create new habitat and that risks with this action are understood and have been mitigated. Import rocks that have similar attributes to those used naturally by GS onto the Bogong High Plains. Find areas that appear to be suitable GS habitat except for the absence of rocks, add rocks to 4 of these areas. Monitor rocks to see if they are colonized by GS.

Based on expert assessment the benefit of each action at each location for this species is as follows:

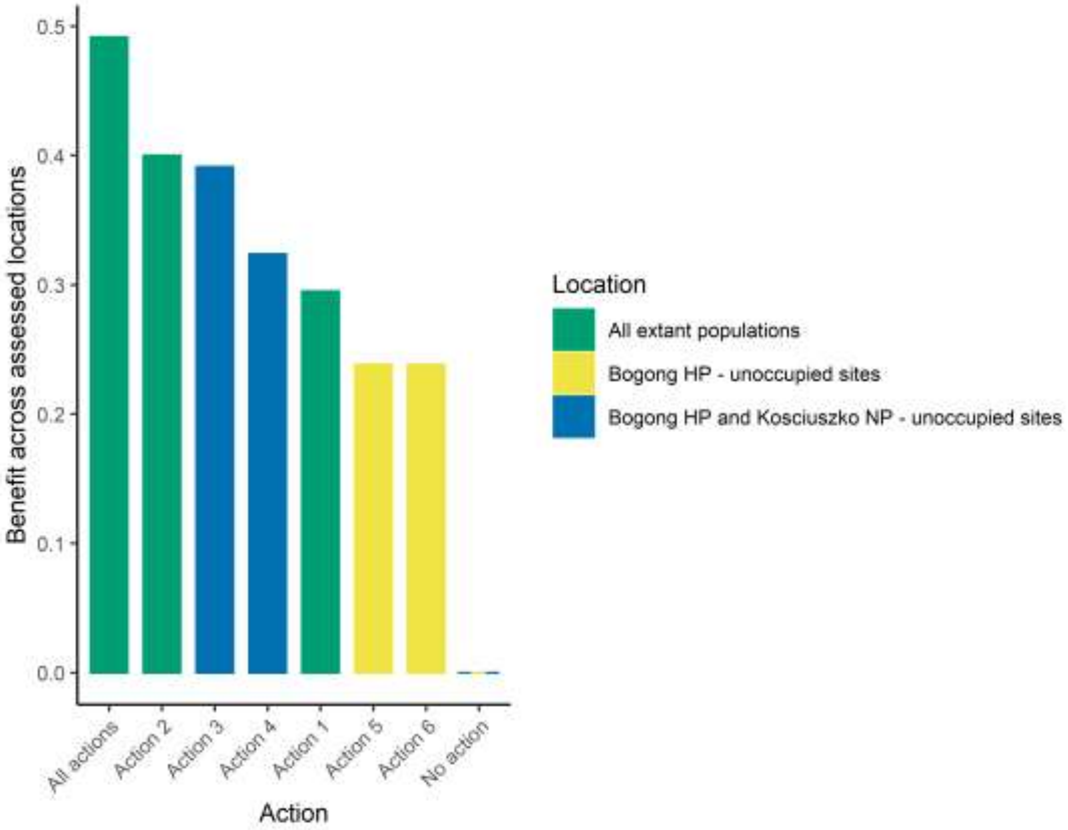

Figure 181. Benefit of each action/location combination to the Guthega Skink overall persistence probability across all assessed locations.

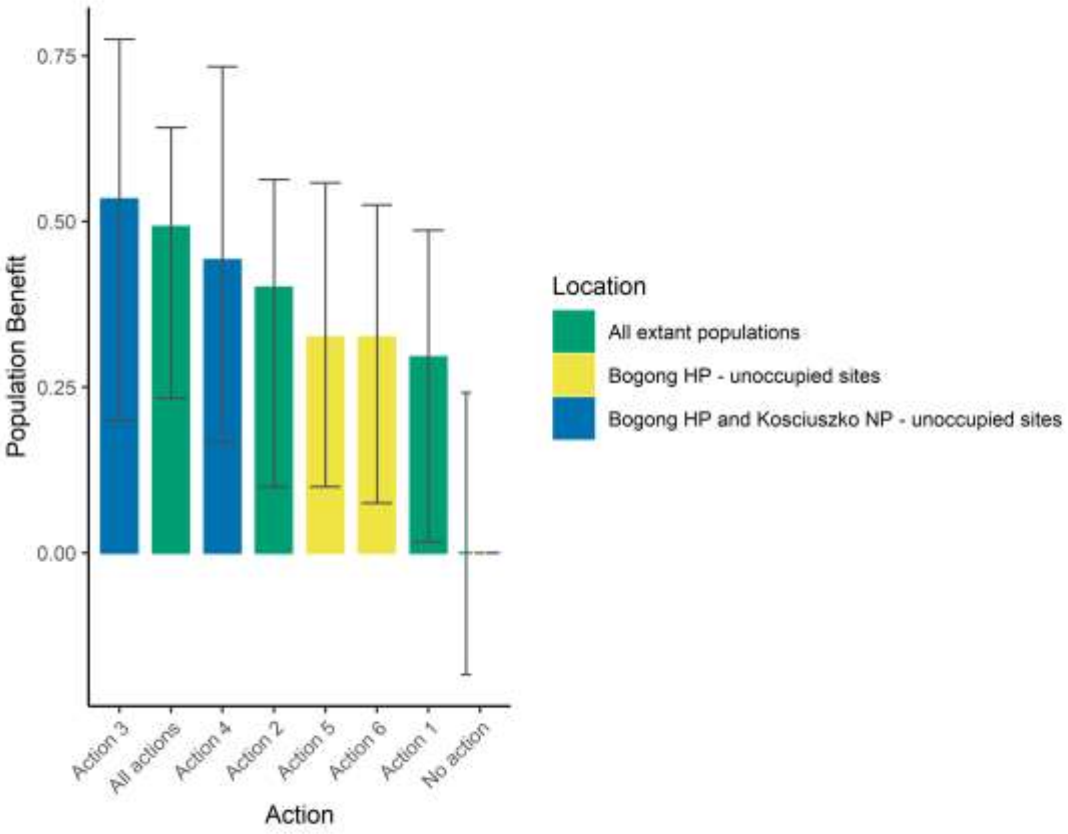

Figure 182. Mean change in Guthega Skink probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Actions for this species centre around boosting resilience across the landscape through translocation, gene mixing and captive breeding. From the resulting rankings, the creation of a new habitat (action 6) or movement to a novel habitat (action 5), may be less beneficial than reintroduction into currently unoccupied sites.

Species: Masters' Snake (*Drysdalia mastersii*)

Number of experts: 5

Locations: Big Desert and private properties

Current population in Victoria: Known only from the Big Desert and nearby isolates in the Victorian Mallee.

#	Actions:	
	No action	No management of wild populations.
1	Apply fire regime determined by most relevant herpetologists to be appropriate for Masters' Snake	Too frequent burning of habitat within the known and probable range of Masters' Snake changes to a fire regime suitable for the species as directed by the most relevant herpetologists, allowing spinifex to mature, and leaf litter and ground debris to accumulate.
2	Identification and appropriate management of fire refuges	Use fire mapping and knowledge generated by previous work (P. Robertson and N. Clemann unpublished data) to identify long unburnt remnants in the Big Desert and surrounding patches of land. Pre-emptively prevent fire in these areas as they are assessed. Conduct survey (pitfall trapping, with number of trap lines relative to size of remnant land or area of old growth patch) to try to detect Masters' Snake. Manage patches sympathetically for the snake (allow habitat to reach an age where spinifex matures, and leaf litter and ground debris accumulates. As spinifex senesces, conduct very small planned burns guided by the most relevant herpetologists.
3	Reintroductions into unoccupied refuges	Assuming survey has indicated that an apparently suitable patch of habitat (or a patch that will be suitable in coming years) is probably not occupied by Masters' Snake, and that robust surveys have found a suitably large/healthy population that can support a wild-to-wild translocation-reintroduction program, or that an appropriate captive breeding program has been established and has produced enough suitable offspring to support a reintroduction program, conduct reintroductions (preferably in an experimental framework). Establish a suitable long term (20+ years) post-release monitoring program to determine the outcomes of the reintroductions, and to refine the program if necessary.
4	Captive program	Assuming that funding for surveys is made available, and surveys locate extant populations, and those populations are determined to be able to cope with removal of sufficient numbers of individuals, establish a captive program from wild-caught snakes. The initial aim of the program is to develop husbandry protocols such that the species can be bred at will in captivity. Ideally have captive animals held by at least two zoos to spread risk. Aim to produce sufficient genetically healthy offspring to enable reintroduction to multiple sites on both private and public land.
5	Translocations	Assuming that funding for surveys is available, and surveys locate extant populations that are able to cope with removal of sufficient numbers of individuals for either or both of a wild-to-wild or captive to wild reintroduction program (dependent on establishment and success of a captive program), plan and conduct such a program, and monitor the outcomes, refining habitat and pest management as per guidance from species' experts.
-	Analyse species response to fire / Generate time since fire curves	Although only one individual of the species has been recorded at only one location in Victoria in recent decades, if at some point in the future other populations can be found that are sufficient in number to allow enough data to be collected, generate time since fire curves.

Based on expert assessment the benefit of each action at each location for this species is as follows:

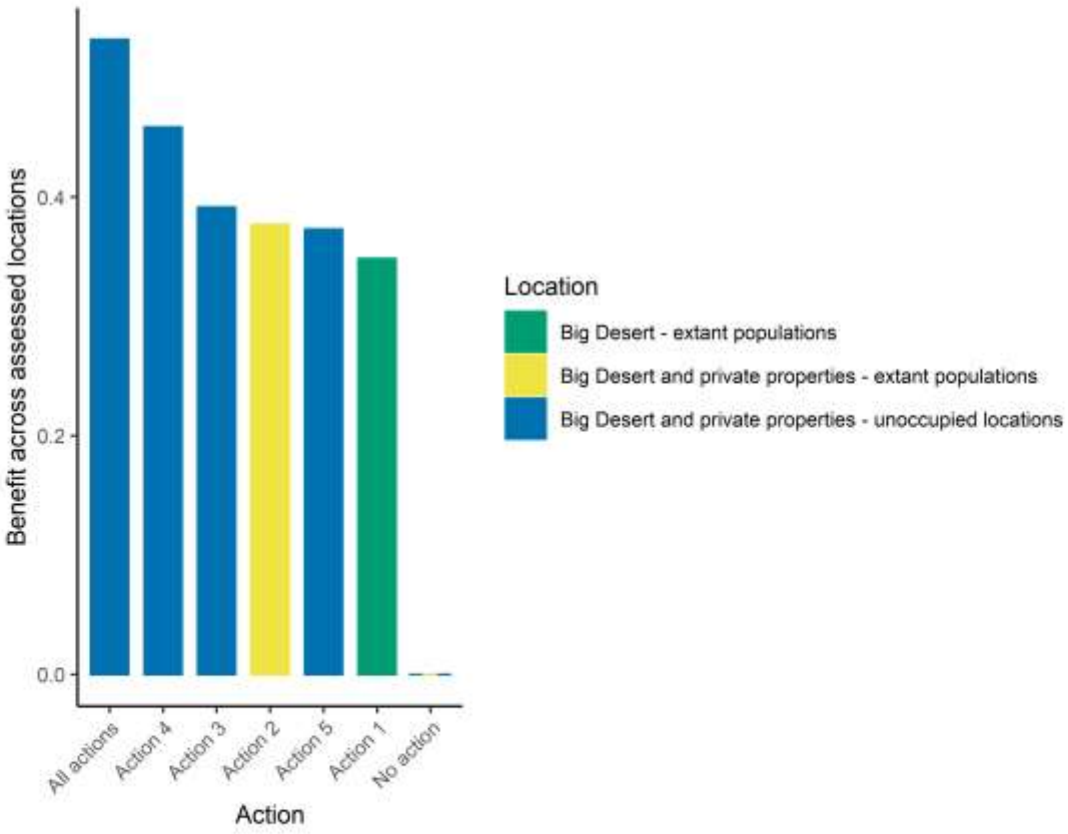

Figure 183. Benefit of each action/location combination to the Masters' Skink overall persistence probability across all assessed locations.

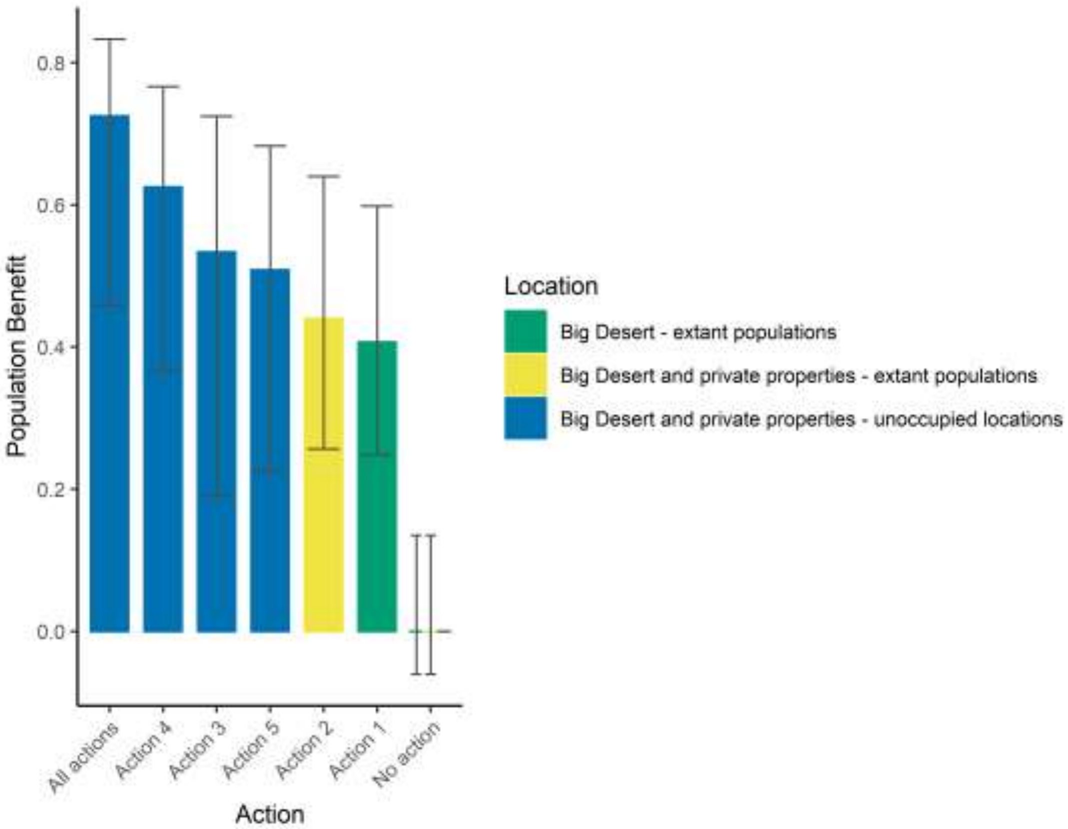

Figure 184. Mean change in Master' Snake probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

This species is predicted to show high level benefits from translocation to unoccupied habitat in Big Desert and private properties, which would be most effective when targeted at refuges (action 3) and/or supported by a captive breeding program (action 4).

Species: Mountain Skink (*Liopholis montana*)

Number of experts: 6

Locations: Montane sites east and north-east of the Yarra Valley and all extant populations.

Current population in Victoria: Known from disjunct localities from as far west as the Yarra Valley and extending through montane to alpine areas to East Gippsland.

#	Actions:	
	No action	No management of wild populations.
1	Captive breeding	Assume survey has found extant populations of appropriate size and genetic health suitable for harvesting animals for a captive program. Establish program being mindful of this species' social needs and a desirable genetic mix. Determine husbandry protocols so that breeding can occur as needed. Breed 100 Mountain Skink (MS) in captivity. Determine why captive bred lizards should be released and assume that 4 suitable release sites have been found to meet that objective. Release MS. Monitor released lizards via a mark-recapture program.
2	Gene mixing	Assume that preliminary work indicates that a gene mixing program is desirable and suitable donor populations have been found. Carefully select individuals from donor and recipient colonies produce offspring in captivity (potentially including NSW animals). Assume that suitable release sites have been found. Consider habitat manipulation prior to release to ensure that released animals have immediate shelter sites upon release. Release a suitable number of these offspring at recipient site(s) and conduct careful monitoring via mark-recapture methods.
3	Reintroduction to currently unoccupied but suitable habitat	Assume that a detailed survey program has determined that suitable habitat is probably unoccupied. Assume donor colonies have been located and are able to sustain necessary harvesting (or use gene mixed animals from captive program). Determine response if reintroduction fails. Conduct wild-to-wild or captive-to-wild reintroduction. Monitor survival, breeding and genetic health using a combination of mark-recapture methods and molecular techniques.
4	Introductions to novel habitat	Assume that introduction to novel habitat has been deemed to be desirable (novel habitat is defined as suitable MS habitat that is not currently occupied and has not been occupied previously). Assume novel habitat has been found, and that suitable donor populations have been found. Determine response if introduction fails. Collect lizards from donor populations for introductions, or use animals produced by the captive breeding program. Release lizards in mid-summer. Monitor survival and breeding using a combination of mark-recapture methods and molecular techniques.
5	Creation of new habitat	Determine what 'creation of new habitat' means. Determine why 'new habitat' would be created. Determine where new habitat should be created. If 'new habitat' is to be created within the geographic range of an existing population, determine what the objective of doing so is. If 'new habitat' is to be created within the geographic range of an existing population, conduct a thorough risk assessment to understand the possible/probable negative consequences. Determine if those consequences could be mitigated/reversed. Determine whether potential consequences were worth the risk. Create 4 patches of 'new habitat'. Carefully monitor new habitat to see if MS find and use 'new habitat'. If possible, reverse negative consequences if/when problems are detected.

Based on expert assessment the benefit of each action at each location for this species is as follows:

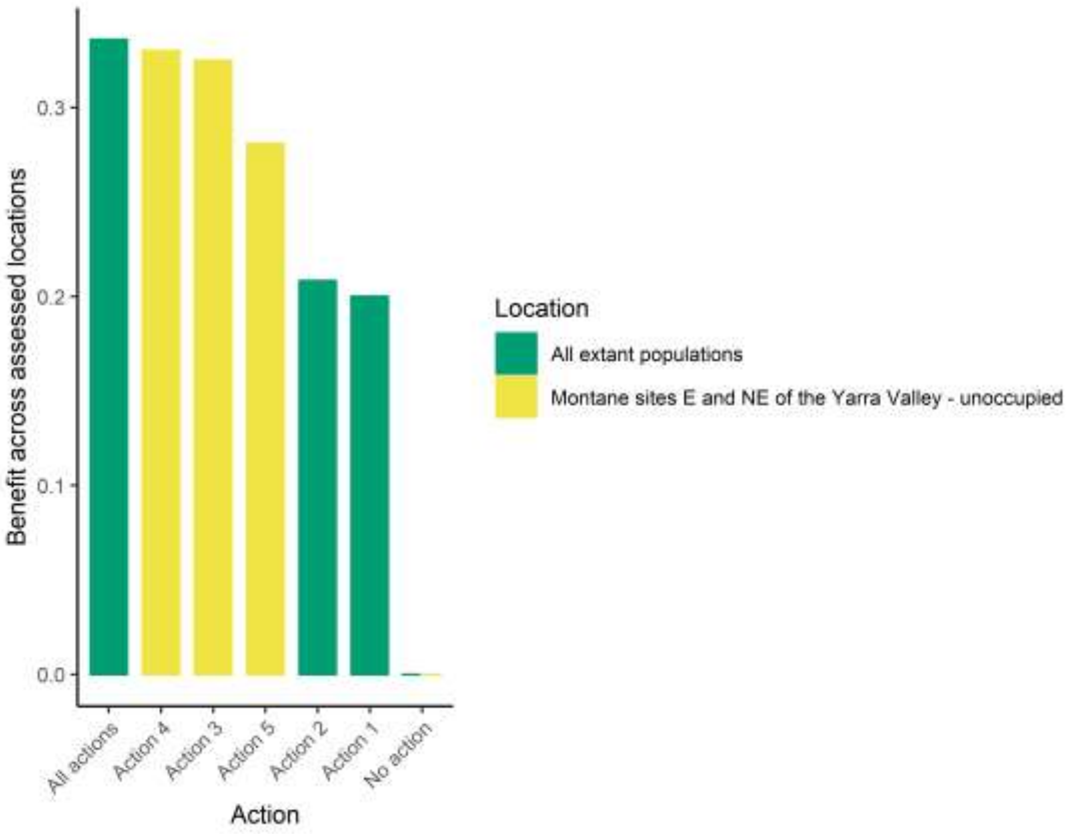

Figure 185. Benefit of each action/location combination to the Mountain Skink overall persistence probability across all assessed locations.

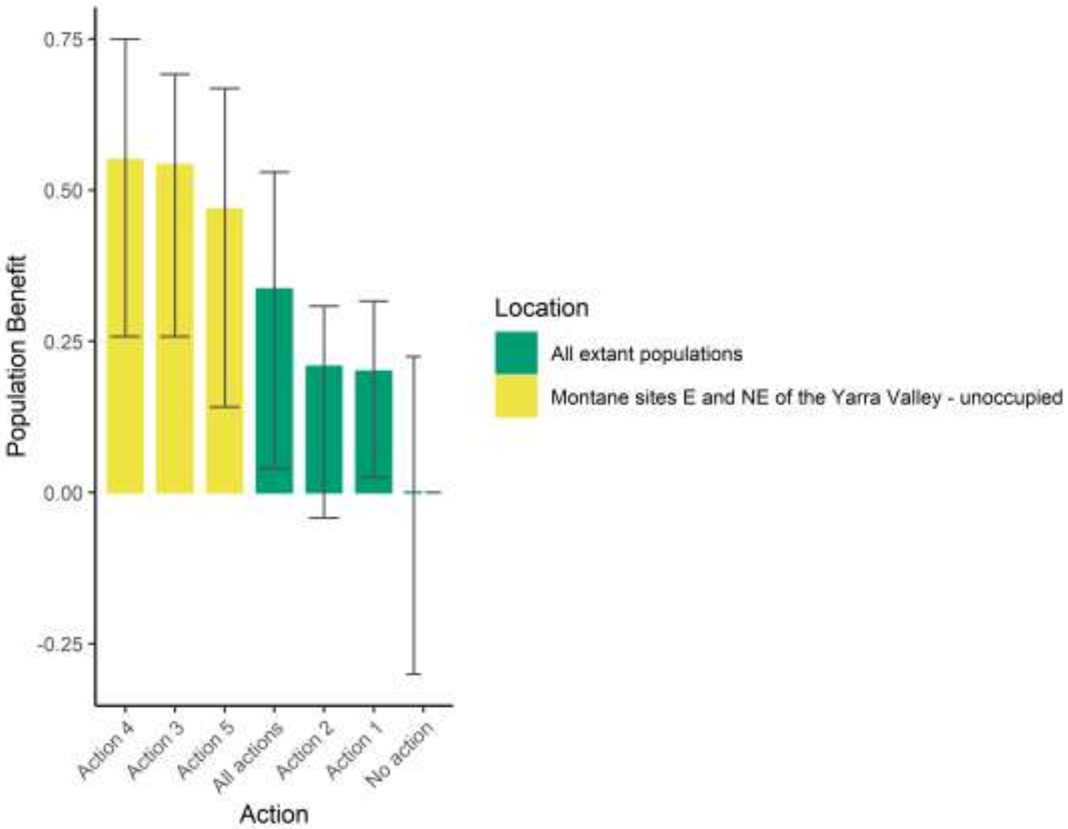

Figure 186. Mean change in Mountain Skink probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Actions considered here are similar to other reptiles in this assessment, with the Mountain Skink likely to benefit from translocation, both to new sites (action 4) or reintroduction to suitable habitat that is currently unoccupied (action 3). Captive breeding and gene mixing of extant populations show some benefit, but do not contribute as highly to probability of persistence.

Species: Swamp Skink (*Lissolepis coventryi*)

 # experts: 5

Locations: Southern Victoria (known and possible habitat) and all extant populations.

Current population in Victoria: Disjunct populations in southern Victoria, from East Gippsland to the South Australian border. Extends as far inland as the Grampians.

#	Actions:	
	No action	No management of wild populations.
1	Wetland protection and restoration	Prevent further destruction and degradation of known or possible habitat in Victoria. If any areas remain where habitat is degraded but not completely destroyed, conduct careful habitat management and restoration, as per the guidelines of Robertson and Clemann (2015. To be provided to people completing the elicitation).
2	Assess potential for gene mixing for resilience	Assume that surveys for the species across its Victorian range and subsequent molecular analyses indicate that gene mixing is desirable. Collect lizards from chosen populations and conduct captive trials to determine the benefits or otherwise of gene mixing for this species. If the trials indicate that this approach is desirable, determine whether to use wild-to-wild translocations, captive bred lizards, or a combination of both to undertake gene mixing in wild populations.

Based on expert assessment the benefit of each action at each location for this species is as follows:

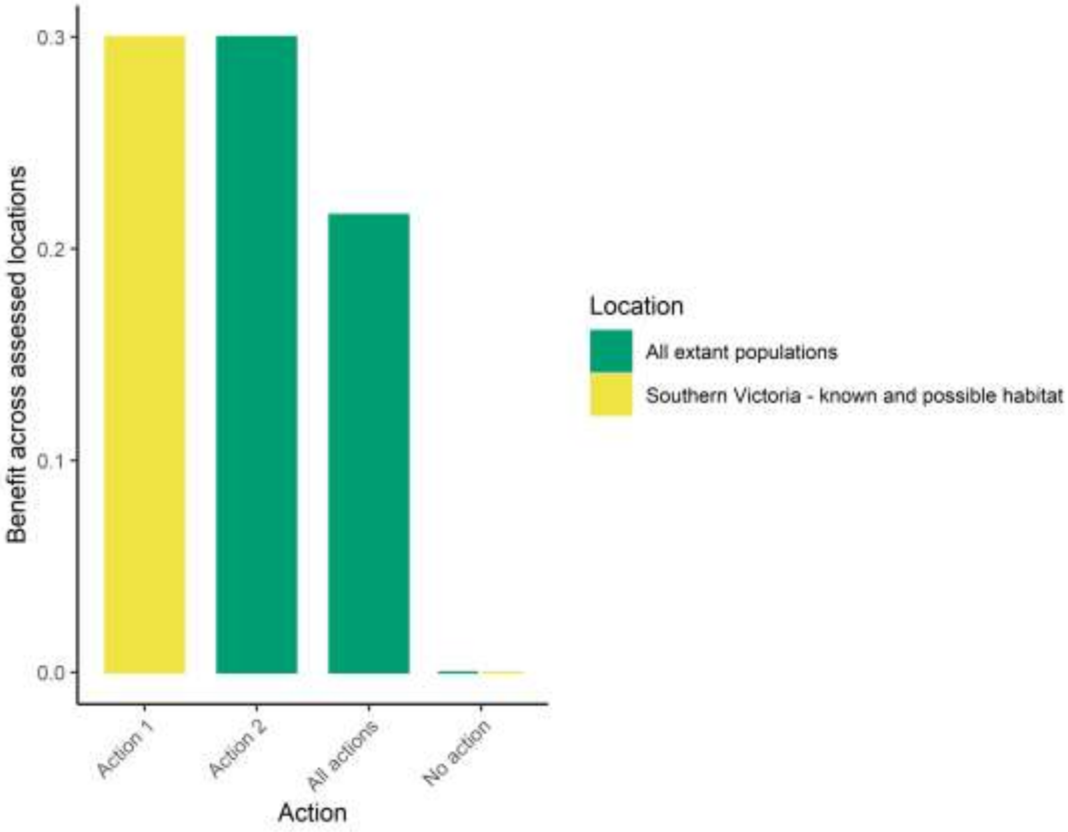

Figure 187. Benefit of each action/location combination to the Swamp Skink overall persistence probability across all assessed locations.

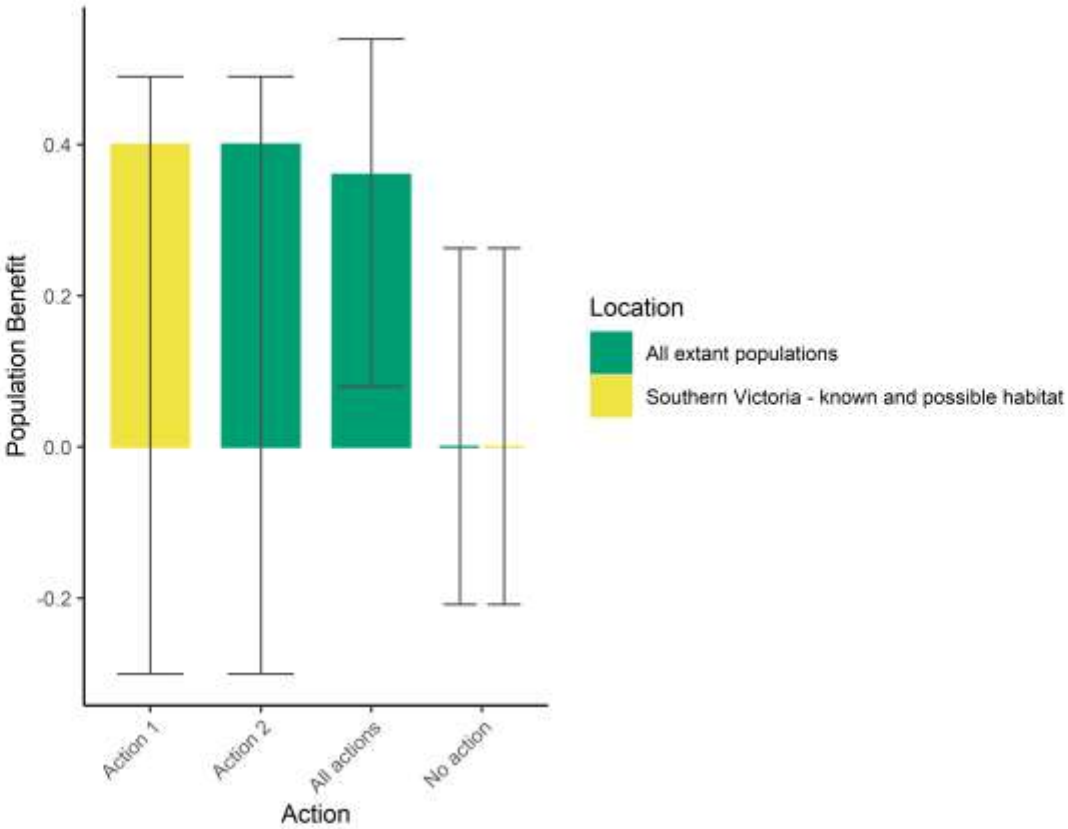

Figure 188. Mean change in Swamp Skink probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Wetland protection and restoration (action 1) and assessment of the potential for gene mixing (action 2) show an equal potential benefit for Swamp Skink at each relevant location. Both these actions across all extant populations shows a lower estimated benefit but is less likely to have a disbenefit in the worst case.

Species: Gippsland Water Dragon (*Intellagama lesueurii howittii)*

Number of experts: 6

Locations: Extant populations and currently or previously occupied locations.

Current population in Victoria: Coastal side of the Great Dividing Range, from East Gippsland as far west as the Thompson catchment. Introduced populations occur in some locations on the Yarra River and individuals are occasionally found on other water courses around Melbourne and Geelong; these introduced populations are often a mix of both subspecies of Water Dragons.

#	Actions:	
	No action	No management of wild populations. NOTE: Unlike the other species, no actions for this subspecies were produced from the first workshop. Consequently, the actions listed here have been generated by the reptile lead.
1	Genetic rescue	Evaluate need for genetic rescue.
2	Conduct gene mixing and monitor the results	Assume that previous field and captive work shows that gene mixing would be beneficial. Conduct wild-to-wild translocations, or release of captive bred lizards, or both, to wild populations. Monitor outcomes.
3	Augment or reintroduce wild populations	Assume that surveys indicate that Water Dragons have been lost from key areas, or have declined to the extent that augmentation of struggling populations is desirable. Augment or reintroduce populations via wild-to-wild translocations, or release of captive bred lizards, or both, to wild populations.

Based on expert assessment the benefit of each action at each location for this species is as follows:

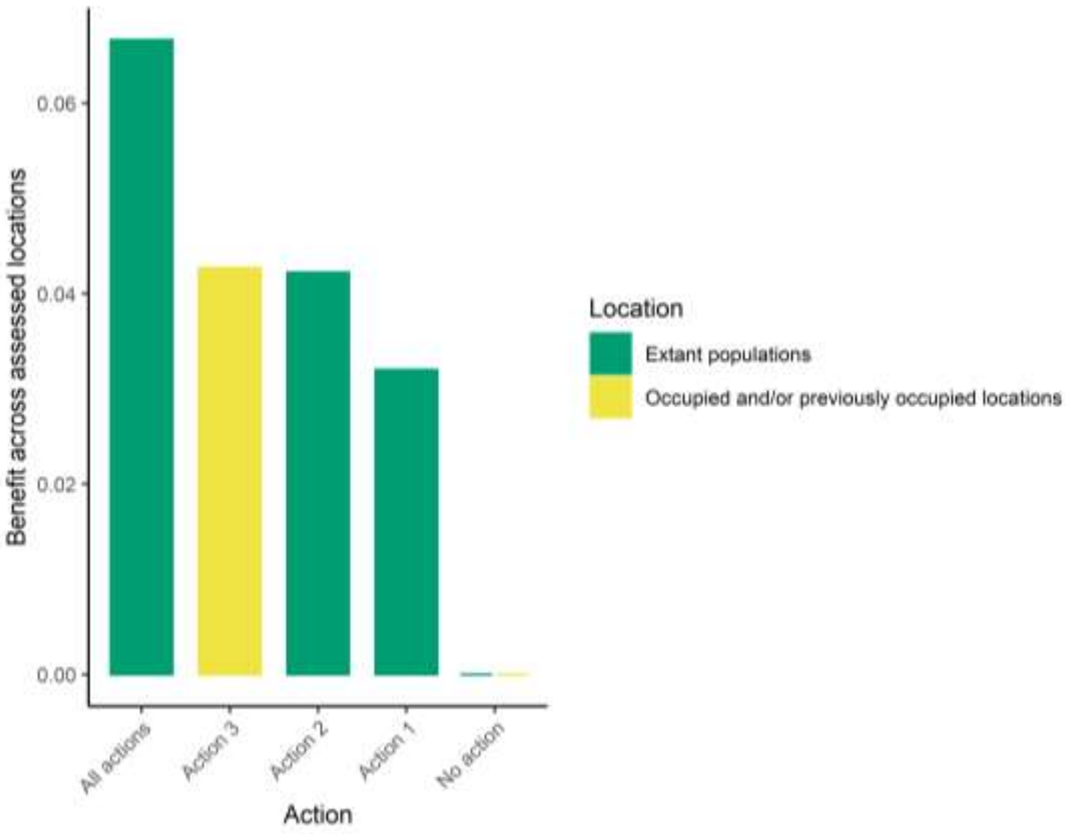

Figure 189. Benefit of each action/location combination to the Gippsland Water Dragon overall persistence probability across all assessed locations.

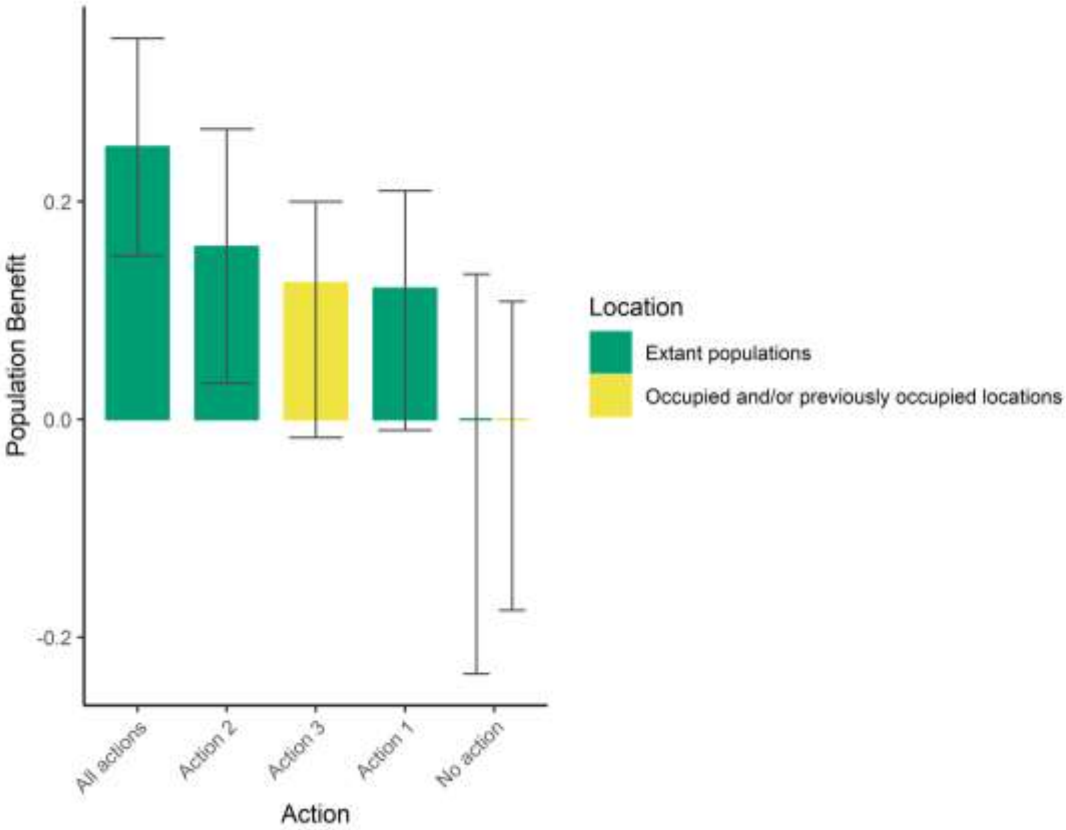

Figure 190. Mean change in Swamp Skink probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Gene mixing with result monitoring (action 2) shows the greatest potential benefit in extant populations. When considering benefit across all locations, this is likely to have a comparable benefit to reintroduction or augmentation at an occupied and/or previously occupied site. All actions show the greatest potential gain, however, are not additive. Genetic rescue is the lower ranked of the two actions in extant populations and has the potential for a slight disbenefit at a population scale.

Species: Bardick (*Echiopsis curta)*

Number of experts: 6

Locations: Little Desert, Big Desert and Murray Sunset National Park.

Current population in Victoria: All extant populations and unoccupied locations in the Little Desert, Big Desert and Murray Sunset National Park.

#	Actions:	
	No action	No management of wild populations.
1	Apply fire regime determined by appropriate herpetologists to be appropriate for Bardick	Too frequent burning of habitat within the known and probable range of Bardick changes to a fire regime suitable for the species as directed by the most relevant herpetologists, allowing spinifex to mature, and leaf litter and ground debris to accumulate.
2	Identification and appropriate management of fire refuges	Use fire mapping and knowledge generated by previous work (P. Robertson and N. Clemann unpublished data) to identify long unburnt remnants in the Big Desert and surrounding patches of land. Pre-emptively prevent fire in these areas as they are assessed. Conduct survey (pitfall trapping, with number of trap lines relative to size of remnant land or area of old growth patch) to try to detect Bardick. Manage patches sympathetically for the snake (allow habitat to reach an age where spinifex matures and leaf litter and ground debris accumulates. As spinifex senesces, conduct very small planned burns guided by the most relevant herpetologists).
3	Reintroductions into unoccupied refuges	Assume that extensive survey indicates that an apparently suitable patch of habitat (or a patch that will be suitable in coming years) is probably not occupied by Bardick, and robust surveys have found a suitably large/healthy population that can support a wild-to-wild translocation-reintroduction program, or an appropriate captive breeding program has been established and has produced enough suitable offspring to support a reintroduction program. Conduct reintroductions (preferably in an experimental framework). Establish a suitable long term (20+ years) post-release monitoring program to determine the outcomes of the reintroductions, and to refine the program if necessary.
4	Captive program	Assume surveys have located extant populations that are able to cope with removal of sufficient numbers of individuals to establish a captive program. The initial aim of the program is to develop husbandry protocols such that the species can be bred at will in captivity. Captive animals are held by at least two zoos to spread risk. Produce enough genetically healthy offspring to enable reintroduction to multiple sites on both private and public land.
5	Translocations	Assume surveys have located extant populations that are able to cope with removal of sufficient numbers of individuals to allow for either or both of a wild-to-wild or captive-to-wild reintroduction program (assume establishment and success of a captive program), plan and conduct such a program, and monitor the outcomes, refining habitat and pest management as per guidance from species' experts.
	Analyse species response to fire / - Generate time since fire curves	Use existing data and data from surveys assumed above to generate time since fire curves.

Based on expert assessment the benefit of each action at each location for this species is as follows:

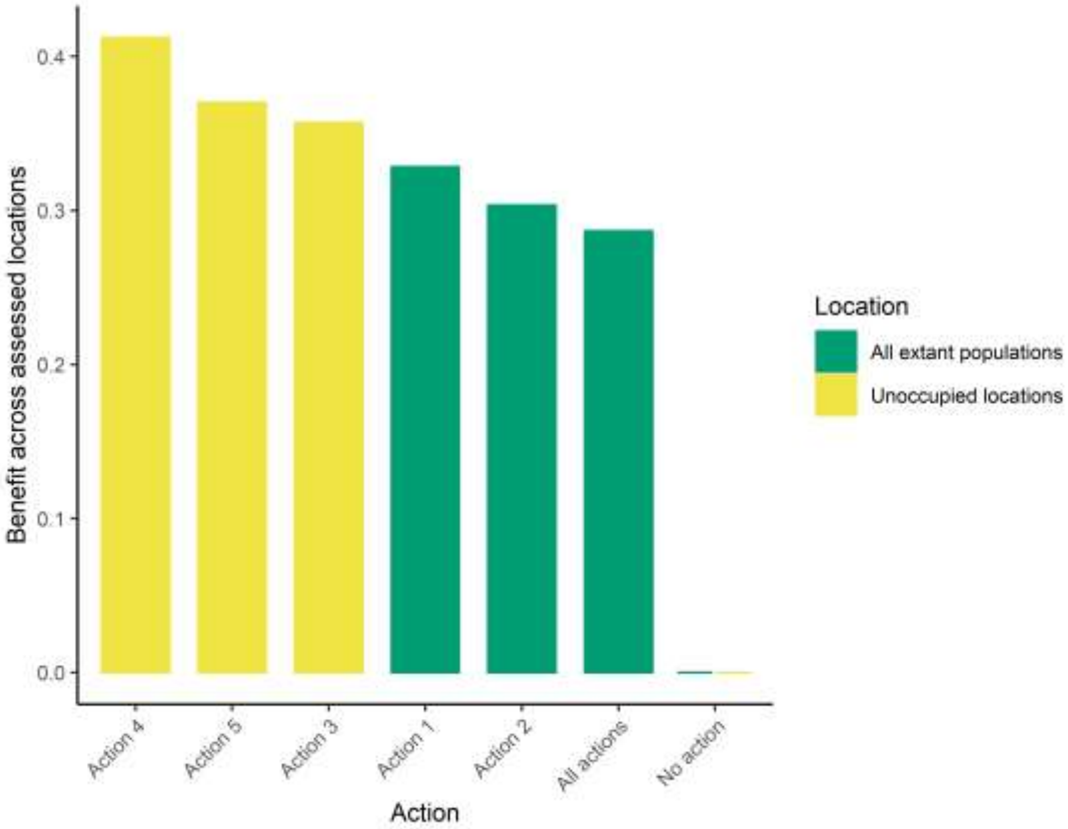

Figure 191. Benefit of each action/location combination to the Bardick overall persistence probability across all assessed locations.

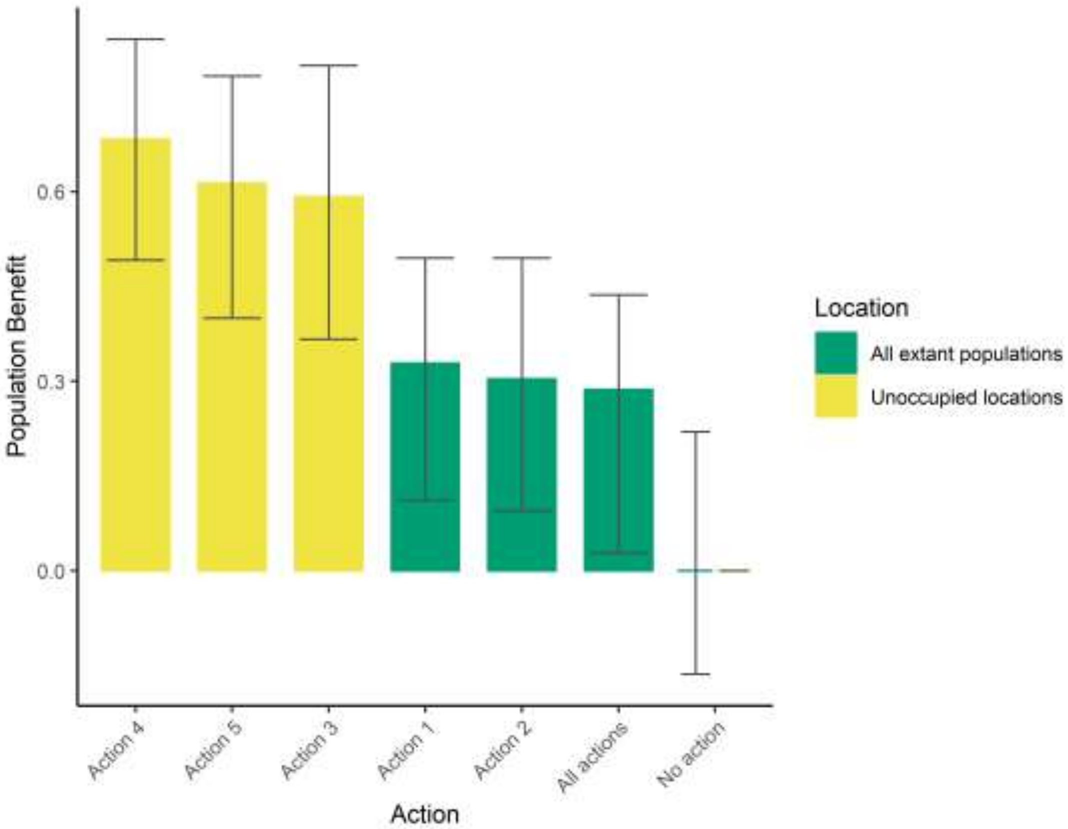

Figure 192. Mean change in Bardick probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Actions chosen for this assessment demonstrate that the major threat in extant populations of Bardick is fire. Appropriate and more strategic fire management (action 1) with a focus on refuges (action 2) will have a reasonable benefit, however translocation and reintroduction to unoccupied locations will have a stronger benefit to probability of persistence, particularly at each location.

Flora

Introduction

Species selected for this analysis focuses on endemic threatened (or near threatened) Victorian flora that are at some risk of extinction by 2070. Exceptions were made for several threatened rainforest or wet forest plants from eastern Victoria which are, or were, common in NSW. These species are threatened by bushfires and it is likely that the 2019-20 bushfires significantly impacted many of their NSW populations, and therefore, consideration of their conservation is warranted in DELWP's Specific Needs process.

See supplementary report for further information.

Key knowledge gaps

I. Impact of frequent, low intensity fire on threatened geophytes in box-ironbark forest (and other non-grassy, non-heathy, woodlands and dry forests

Inappropriately frequent fire regimes are often cited as a significant threat to plants from naturally infrequently burnt vegetation types, such as box-ironbark forest. Impacts to geophytes, particularly orchids, from frequent fires are poorly understood. For example, the impact of frequent fires on populations of insect pollinators, critical to the survival of orchids with specialised pollination systems, is almost totally unknown. The interplay of fire with weeds, herbivory and other threats was also explored. Given the widespread use of cool-season fuel reduction burning in our remaining box-ironbark fragments, many of which are near human settlement, a better understanding of their impacts to endemic threatened flora is urgently needed.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

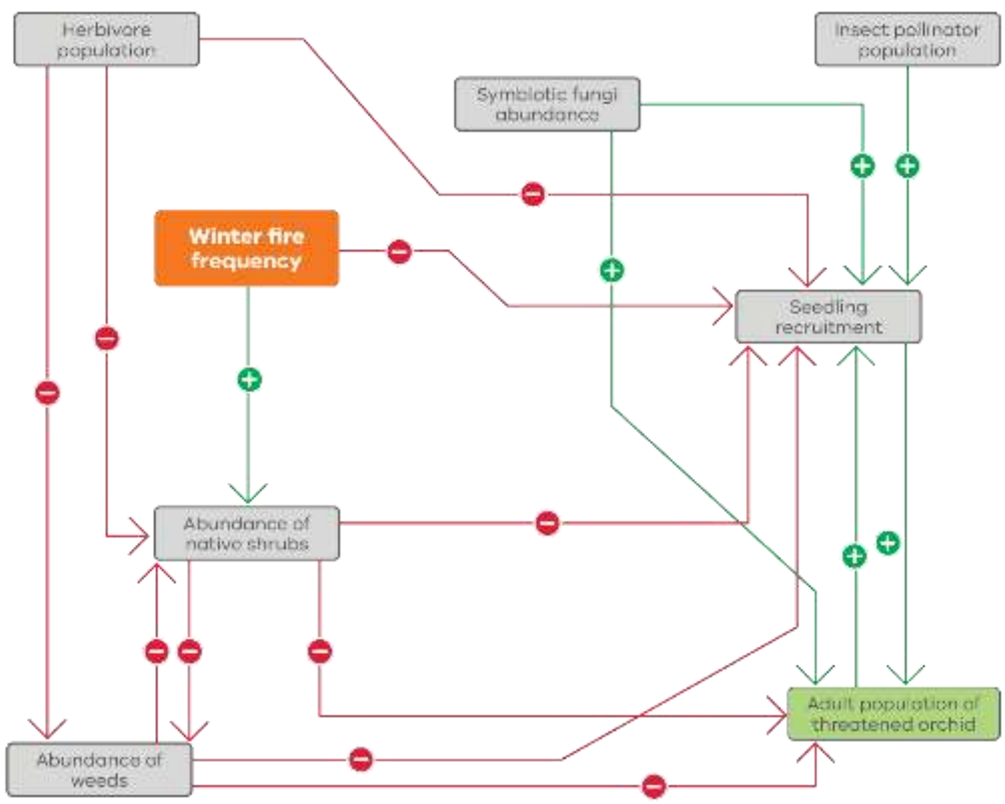

Figure 193. Best case scenario casual model for impact of frequent, low intensity fire on threatened geophytes in box-ironbark forest (and other non-grassy, non-heathy, woodlands and dry forests. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

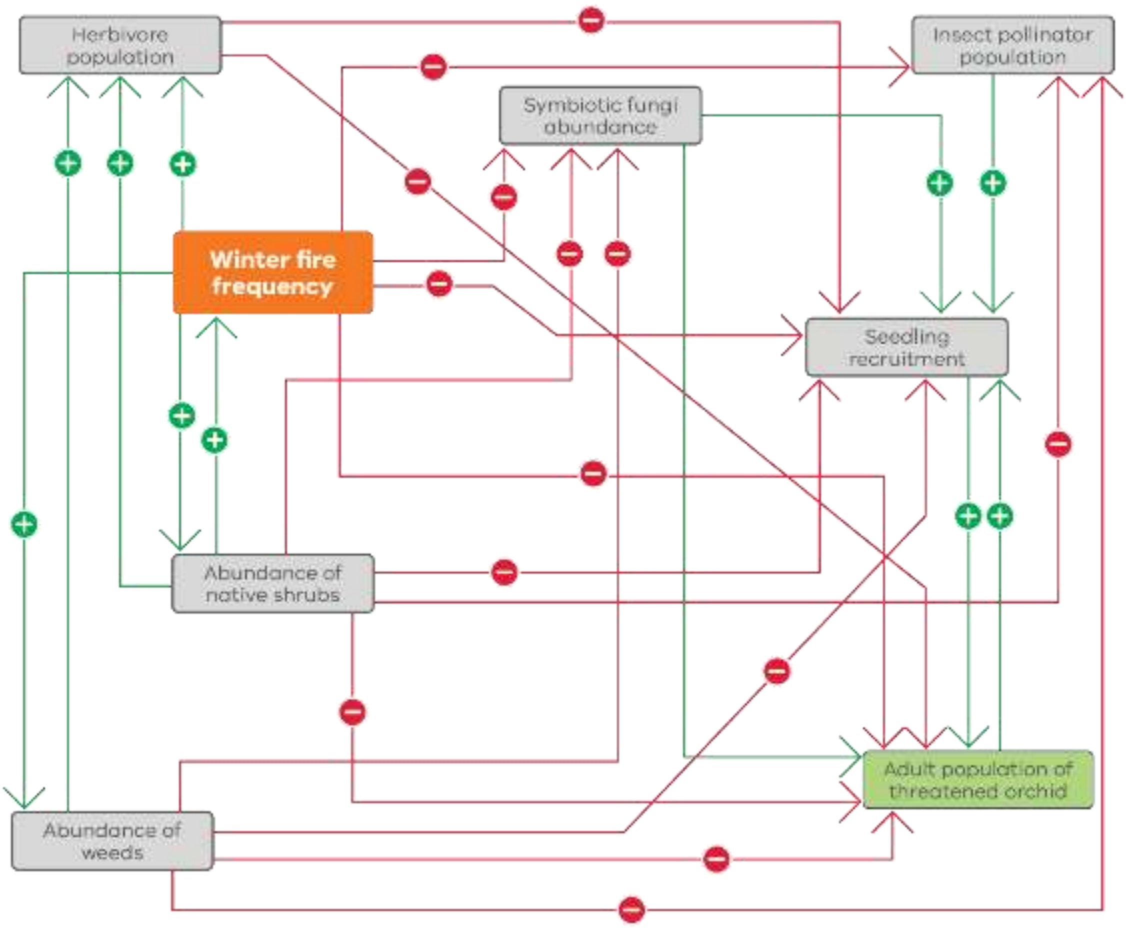

Figure 194. Worst case scenario casual model for impact of frequent, low intensity fire on threatened geophytes in box-ironbark forest (and other non-grassy, non-heathy, woodlands and dry forests. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Winter fire frequency	Insect pollinator population	0.086
2	Herbivore population	Adult population of threatened orchid	0.057
2	Herbivore population	Seedling recruitment	0.057
2	Herbivore population	Abundance of weeds	0.057
2	Abundance of weeds	Adult population of threatened orchid	0.057
2	Abundance of native shrubs	Adult population of threatened orchid	0.057
2	Winter fire frequency	Adult population of threatened orchid	0.057
2	Winter fire frequency	Seedling recruitment	0.057
2	Winter fire frequency	Abundance of weeds	0.057
2	Winter fire frequency	Abundance of native shrubs	0.057
11	Herbivore population	Abundance of native shrubs	0.029
11	Abundance of weeds	Seedling recruitment	0.029
11	Abundance of weeds	Insect pollinator population	0.029
11	Abundance of weeds	Symbiotic fungi abundance	0.029
11	Abundance of weeds	Herbivore population	0.029
11	Abundance of weeds	Abundance of native shrubs	0.029
11	Abundance of native shrubs	Seedling recruitment	0.029
11	Abundance of native shrubs	Insect pollinator population	0.029
11	Abundance of native shrubs	Symbiotic fungi abundance	0.029
11	Abundance of native shrubs	Herbivore population	0.029
11	Abundance of native shrubs	Abundance of weeds	0.029
11	Abundance of native shrubs	Winter fire frequency	0.029
11	Winter fire frequency	Symbiotic fungi abundance	0.029
11	Winter fire frequency	Herbivore population	0.029

Figure 195. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for frequent, low intensity fire on threatened geophytes in box-ironbark forest (and other non-grassy, non-heathy, woodlands and dry forests.

The figure above depicts the ranking of uncertainties from highest to lowest (links where no uncertainty was identified aren't depicted) for this problem-response scenario, with the highest ranked link between winter fire frequency and insect pollinator population (reduction in uncertainty of 0.086). This link might be a good candidate for a research project, as it represents the highest reduction in uncertainty. Other potential candidates for research projects include the links between herbivore population and adult population of threatened orchids, seedling recruitment, and abundance of weeds, abundance of weeds on adult population of threatened orchids, abundance of native shrubs on adult population of threatened orchids, and winter fire frequency on adult population of threatened orchids, seedling recruitment, and abundance of weeds and native shrubs, all of which has a reduction in uncertainty of 0.057.

II. Impact of climate change on threatened alpine and subalpine plants

Victoria has a rich endemic alpine and subalpine flora that is highly susceptible to climate change-driven habitat loss. Although the impacts of climate change on alpine flora has been relatively well-studied, there is much uncertainty around what to do about it. The role of reintroductions or assisted migration for alpine plants is often discussed as a species-saving tool to arrest declines of endemic alpine and subalpine flora due to climate change. However, the experts expressed extreme uncertainty about the effectiveness of reintroductions, a knowledge gap that I sought to highlight in this model. For example, can threatened alpine flora be reintroduced at lower elevations, or would they be outcompeted by other plants? Are their pollinators absent? Does their seed germinate at lower elevations? This model seeks to highlight the knowledge gap around reintroductions for alpine and subalpine flora.

Below are the best- and worst-case scenarios for this system followed by the links ranked in order of discrepancy between models- indicating uncertainty in this system.

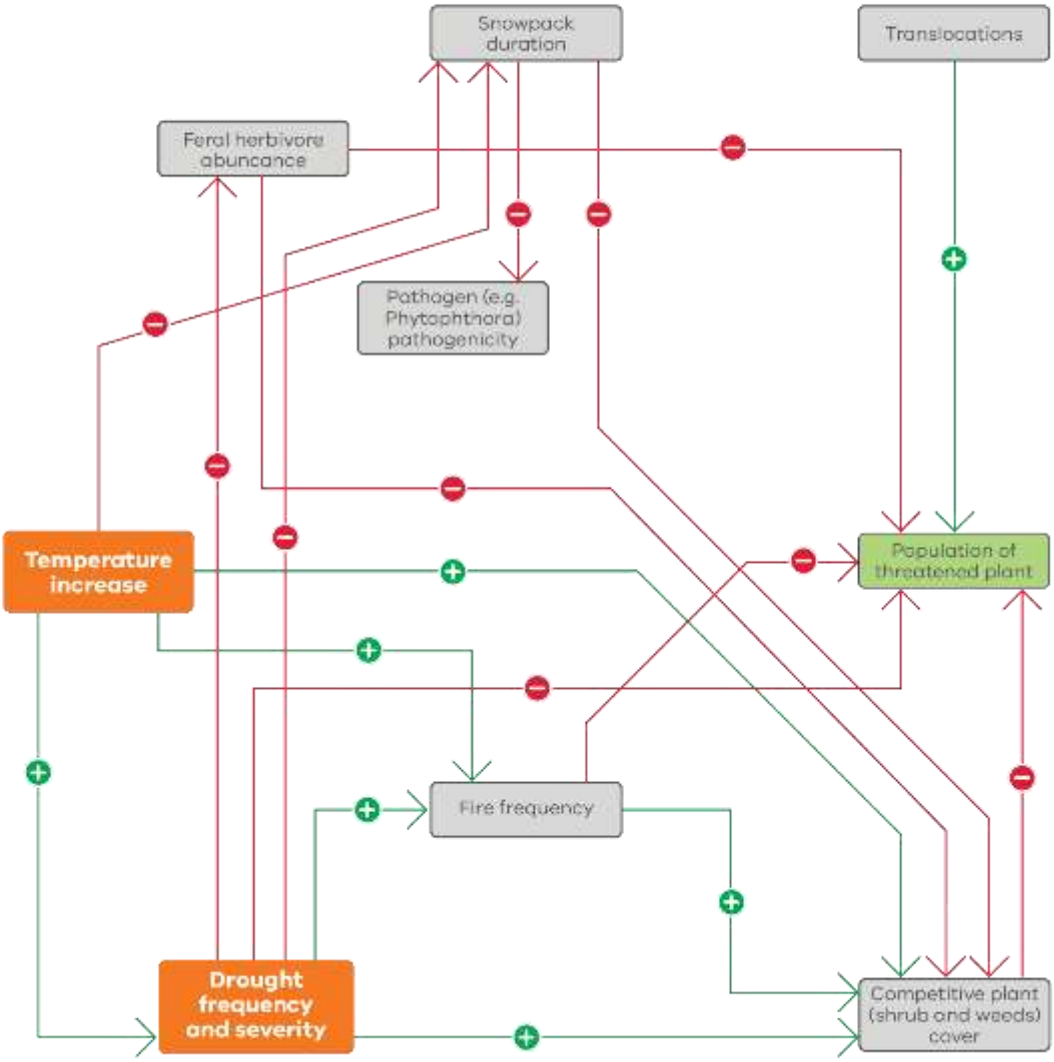

Figure 196. Best case scenario casual model for impact of climate change on threatened alpine and subalpine plants. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

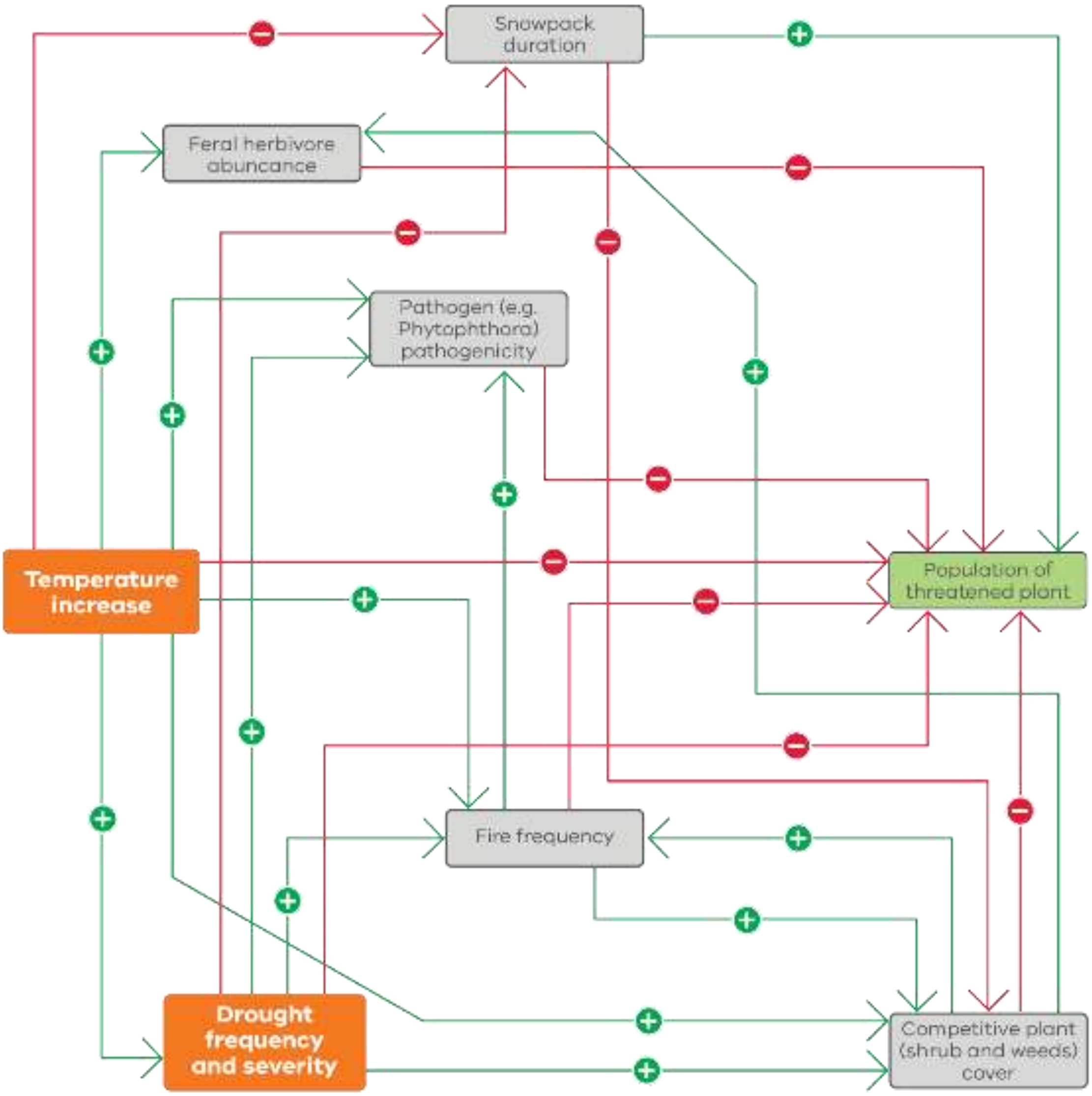

Figure 197. Worst case scenario casual model for impact of climate change on threatened alpine and subalpine plants. Green arrows indicate a positive relationship between nodes, whereas red arrows indicate a negative relationship.

Rank	From	To	Proportional reduction
1	Translocations	Population of threatened plant	0.561
2	Temperature increase	Pathogen pathogenicity	0.056
3	Temperature increase	Competitive shrub and weed cover	0.028
3	Temperature increase	Feral herbivore abundance	0.028
3	Temperature increase	Pathogen pathogenicity	0.028
3	Drought frequency and severity	Competitive shrub and weed cover	0.028
3	Drought frequency and severity	Feral herbivore abundance	0.028
3	Drought frequency and severity	Pathogen pathogenicity	0.028
3	Drought frequency and severity	Population of threatened plant	0.028
3	Fire frequency	Competitive shrub and weed cover	0.028
3	Fire frequency	Pathogen pathogenicity	0.028
3	Fire frequency	Population of threatened plant	0.028
3	Snowpack duration	Competitive shrub and weed cover	0.028
3	Snowpack duration	Pathogen pathogenicity	0.028
3	Snowpack duration	Population of threatened plant	0.028
3	Competitive shrub and weed cover	Fire frequency	0.028
3	Competitive shrub and weed cover	Feral herbivore abundance	0.028
3	Competitive shrub and weed cover	Population of threatened plant	0.028
3	Feral herbivore abundance	Competitive shrub and weed cover	0.028
3	Pathogen pathogenicity	Population of threatened plant	0.028

Figure 198. Prioritised knowledge gaps though proportional reduction in uncertainty from resolving target elements for climate change on threatened alpine and subalpine plants.

The highest ranked link by far was between translocations and population of threatened plants (reduction in uncertainty of 0.561). This might be a good candidate for a research project, as it represents the highest reduction in uncertainty.

Priority medium term conservation actions

A Specific Needs Assessment measures benefit as change in probability of persistence because of the actions described in the following tables, compared to no action, at a particular location. Assessments are spatially explicit, making it possible to consider the benefit of actions both at the location where they are undertaken, as well as across the range of locations considered. The two figures (e.g. 184 and 185) following the action tables below, show two alternative ways of viewing the data. The first figure shows the overall benefit across all assessed locations of each action being undertaken at a specific location. Considering benefit across all locations allows the assessment of which actions and locations will likely lead to the greatest benefit for improving overall species persistence. Where all known locations are considered in the Specific Needs Assessment, this first measure equates to change to species persistence resulting from the action – however, where assessments have only considered a subset of locations where the species is extant, this measure only represents the benefit to these *assessed* locations (rather than the whole species' range). The second figure shows the mean change to the species persistence at each location, so is useful when considering the benefit of different actions at a single location. In addition, the second figure presents variation in expert estimates (mean upper to mean lower estimate), where actions with large variation may be more uncertain in terms of efficacy. Cost-effectiveness is yet to be accounted for; therefore, it is expected that combinations of actions will display the greatest benefit.

Species assessed for priority actions are broken up by broad groups in the following sections:

Understory species

Species: *Ballantinia antipoda*

Commonly known as Southern Shepherd's Purse. A small annual plant belonging to the Brassicaceae family. Sites in which it occurs are usually open, containing only light canopy cover from surrounding trees. The habitat is classified as Granitic Hills Woodland Ecological Vegetation. Threats and actions may be generalisable to a wider group of critically threatened annuals.

Number of experts: 3

Location: Mt Alexander

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Netting/caging	Caging or netting (whichever is best) of significant populations/concentrations of *Ballantinia* and annual monitoring/management of caged areas (i.e. if it was done as well as possible.
2	Access restriction and signage	Barrier fencing to deter mountain biking and interpretive signage around significant subpopulations threatened by mountain biking and trampling.
3	Weed control	Ongoing weed control (5 days/year) of high-threat weeds (*Poa bulbosa, P. annua*) by a qualified and experienced operator. (If you think this is risky and could do more harm than good, that can be reflected in your estimates being lower than “no action”).
4	Fire control	No deliberate burning of the populations.
5	Runoff management	Small-scale up-slope barriers to maximise runoff onto important subpopulations (where agreed – e.g. maybe not all subpops in case of a bad storm event).
6	Supplementation	Of Mount Alexander population.
7	Reintroduction**	A reintroduction would involve seed collection from wild plants, ex-situ seed orcharding to collect 30,000 seeds and direct seeding of a reintroduction site in three stages of ~10,000 seeds each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, reintroduction techniques (timing of sowing, use of Gibberellic Acid to break dormancy or not, etc). For the purposes of this survey we have two fiction reintroduction sites: Supplementation of Mt Alexander into a site of suitable habitat that is not currently occupied by *Ballantinia antipoda*; An area of similar habitat at or near Mt Cole. Assume the site chosen was subject to detailed investigations and represented one of the best sites for reintroduction based on our knowledge. Assume there’s no issues with mountain bikers/trampling.

**Reintroductions of *ex-situ*-grown plants to create new wild populations was a frequently suggested recovery action, particularly for the more critically threatened taxa in Groups 1, 3, 4, 10, 11 and 13 (111 taxa). Following clarification (pers. coms. Ella Kelly, DELWP), reintroduction scenarios were based on a single reintroduction (undertaken in three stages) being undertaken at a single location. This meant that the likely success of reintroductions was scored lower by experts than if the reintroduction scenario had involved several separate reintroductions to several different locations, as would typically be the case in a comprehensive reintroduction project. However, the benefit of doing multiple reintroductions can be quantified by adding the probabilities for a single reintroduction (Ella Kelly, DELWP), meaning that although a single reintroduction may be unlikely to be successful, if several reintroductions were undertaken it may be likely that at least one would be successful. While the cost of reintroductions can be relatively high for some taxa, many of these 111 taxa will become extinct in the wild without a reintroduction program. To minimise costs, some experts recommended that a dedicated ongoing ex-situ propagation and reintroduction program for threatened Victorian flora be established, following a model like the Orchid Conservation Program at the Royal Botanic Gardens Victoria.

Based on expert assessment the benefit of each action at each location for this species is as follows:

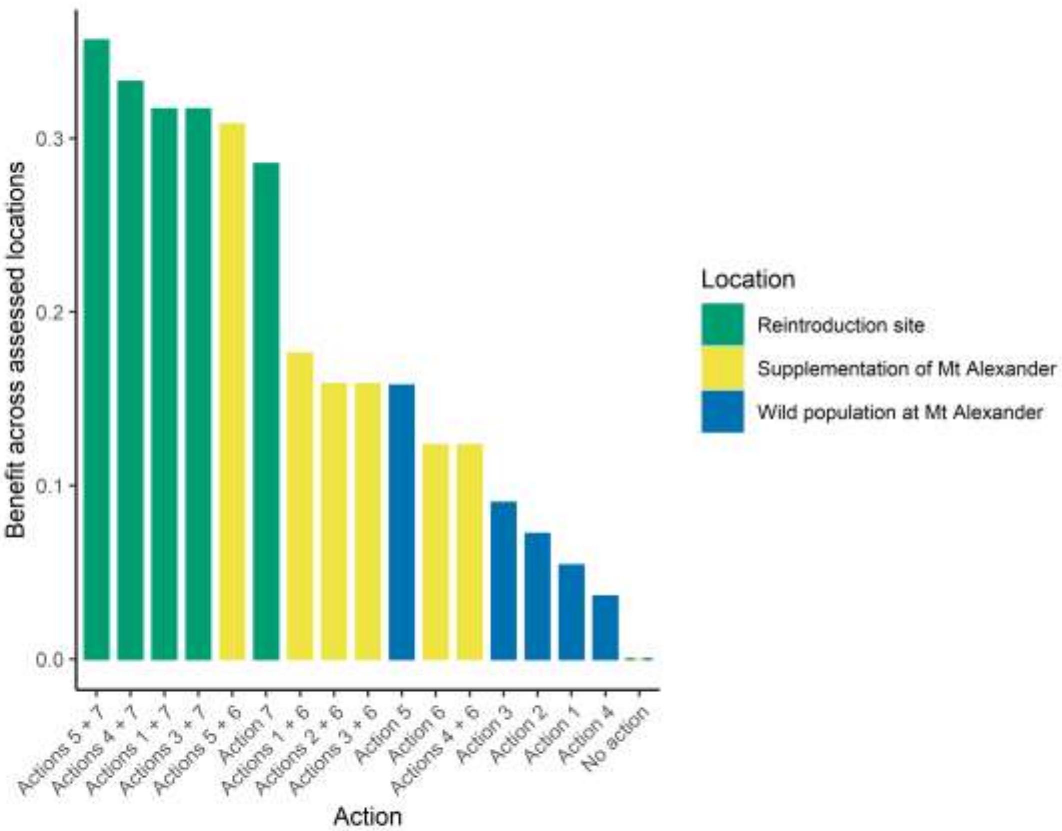

Figure 199. Benefit of each action/location combination to the *Ballantinia antipoda* overall persistence probability across all assessed locations.

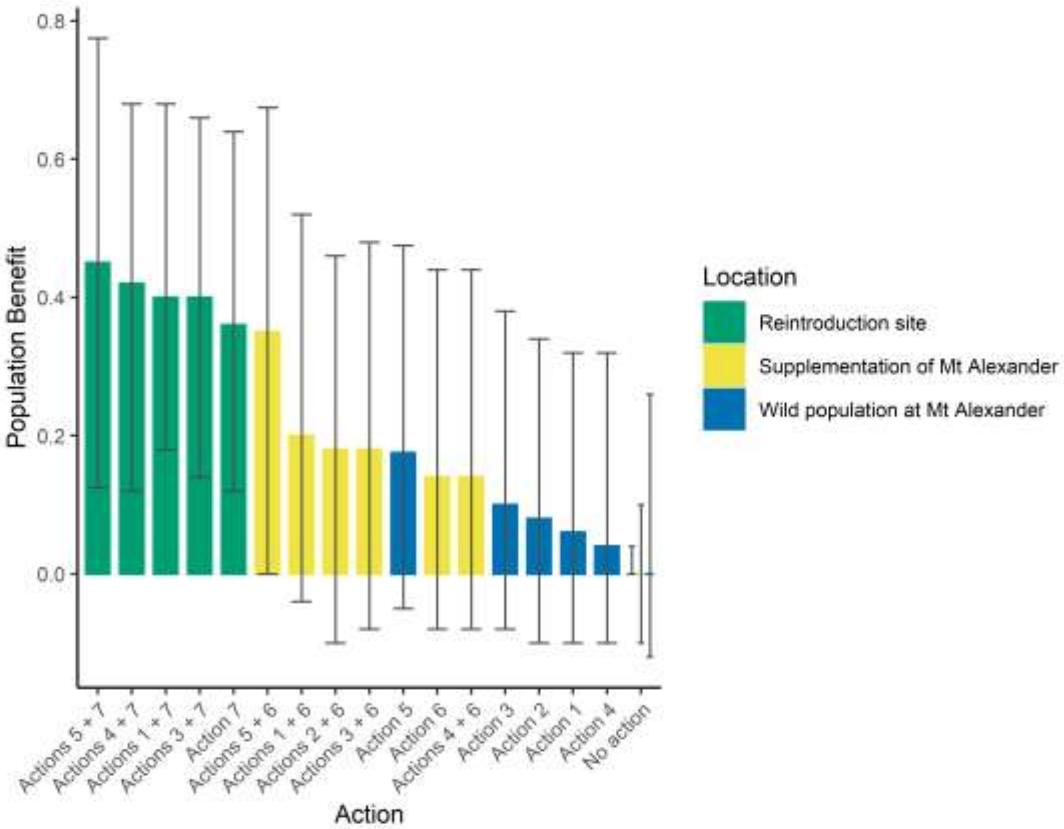

Figure 200. Mean change in *Ballantinia antipoda* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

The clear preference in terms of most beneficial action for this group is reintroduction (action 7). Small boosts are seen with complementary actions 1-5. Supplementation (action 6) to Mt Alexander is also rated as highly beneficial when paired with runoff management (action 5).

Species: *Euphrasia crassiuscula* subsp*. glandulifera*

Commonly known as Thick Eyebright, a perennial herb growing to around 30 cm high. Confined to higher summit areas between Mt Bogong and Mt Hotham, occurring in tall alpine herbfield, and margins of alpine heath, and from open grassy sites, sometimes on stony terrain. Threats and actions may be generalisable to a wider group of similar threatened alpine taxa.

Number of experts: 2

Location: Mt Nelse

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Feral Herbivore control	Ongoing, annual (10 days/year) control of all feral herbivores focused on radius of 20 km from wild populations by most effective available means.

2 3 4	Reintroduction** with fencing with herbivore control	One reintroduction involves seed collection from wild plants and propagation of 1000 1-2 yr old ex-situ grown plants. For the purposes of this survey we have two fictional reintroduction sites: 'Reintroduction site 1' is Bogong High Plains in grassland near old records at Rocky Knobs ~halfway between Pretty Valley and Rocky Valley dams. Fencing probably only feasible at this site. 'Reintroduction site 2' is a site of similar habitat quality and microsite variation to the wild populations but is on Mt Feathertop.

Based on expert assessment the benefit of each action at each location for this species is as follows:

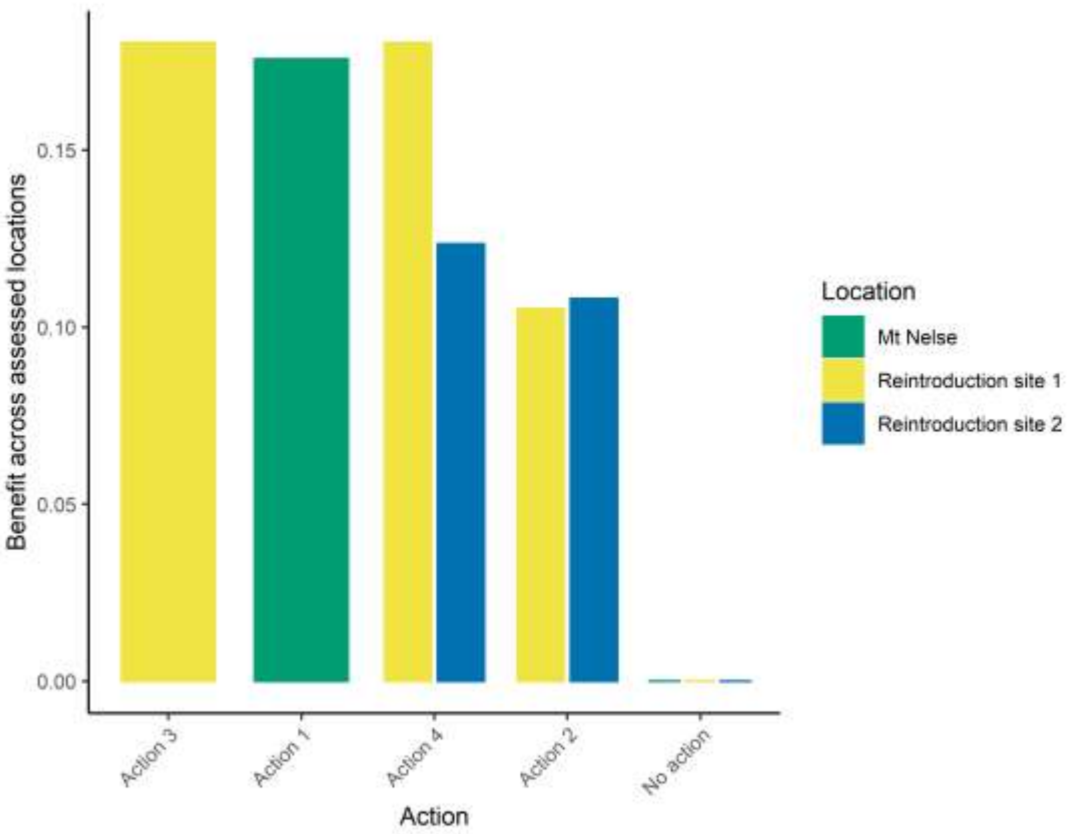

Figure 201. Benefit of each action/location combination to the *Euphrasia crassiuscula* subsp. *glandulifera* overall persistence probability across all assessed locations.

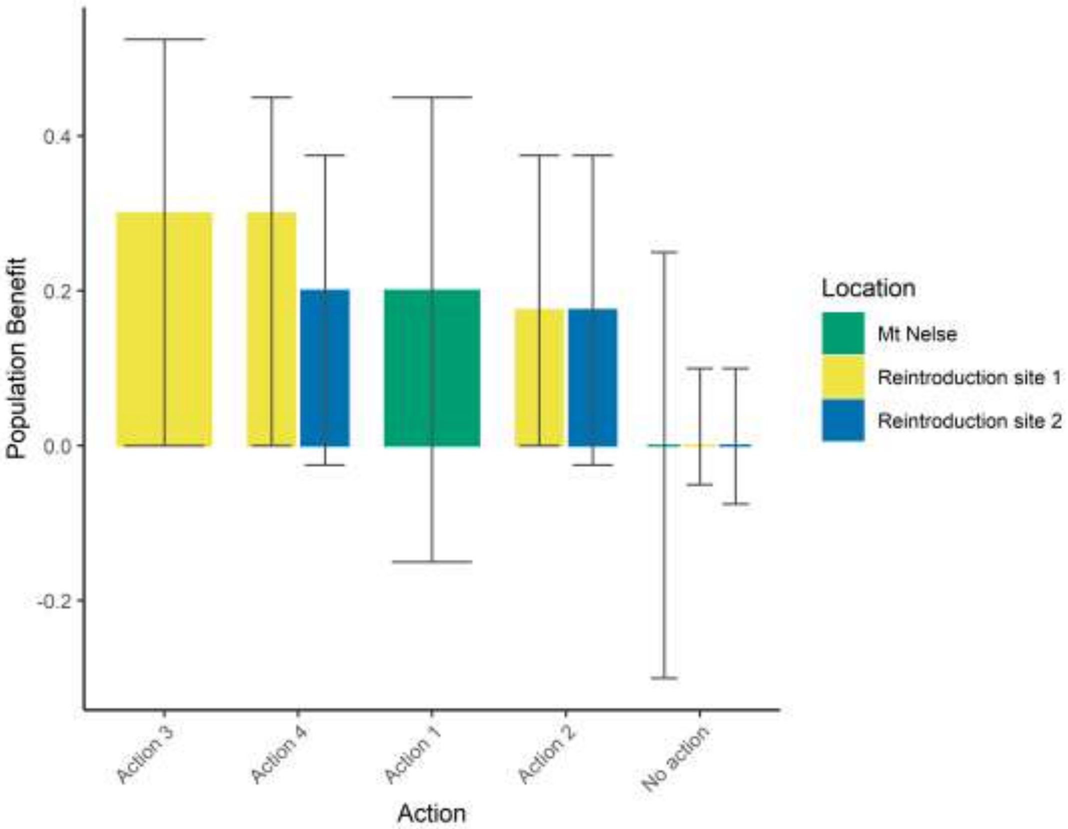

Figure 202. Mean change in *Euphrasia crassiuscula* subsp*. glandulifera* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction to site 1 with fencing or herbivore control is the most beneficial action for this species group. Site 1 shows a greater benefit to overall species probability of persistence when herbivore control is applied, while site 2 is slightly higher with reintroduction alone. Feral herbivore control is the only action considered as potentially beneficial at Mt Nelse.

Species: *Kelleria bogongensis*

Commonly known as Bogon Kelleria, a creeping, mat-forming shrublet. Known only from the Bogong High Plains on basalt-derived soil, growing between snow-grass tussocks in alpine grassland. Threats and actions may be generalisable to a wider group of threatened subalpine grassland/woodland taxa.

 # experts: 2

Location: Mt Jim wild site

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).

1	Fencing	Half the population (or 10 "patches") fenced with several large, feral herbivore-proof fences, each with a minimum area of at least 0.25 ha. Fences are permanently closed (i.e. not opened for periodic grazing) and are subject to ongoing maintenance.
2	Feral Herbivore control	Ongoing annual (10 days/year) control of feral herbivores within a radius of 20 km of the population by most effective available means.
3	Reintroduction**	One reintroduction involves seed collection from wild plants and propagation of 1000 1-2 yr old ex-situ grown plants. For the purposes of this survey we have two fictional reintroduction sites: 'Reintroduction site 1' is a site of similar habitat quality on an area of basalt on the Bogong High Plains to the wild population, incorporating similar microsite variations to those that exist at the wild population. 'Reintroduction site 2' is on Mt Loch and is a site of similar habitat quality and microsite variation to the wild site.

Based on expert assessment the benefit of each action at each location for this species is as follows:

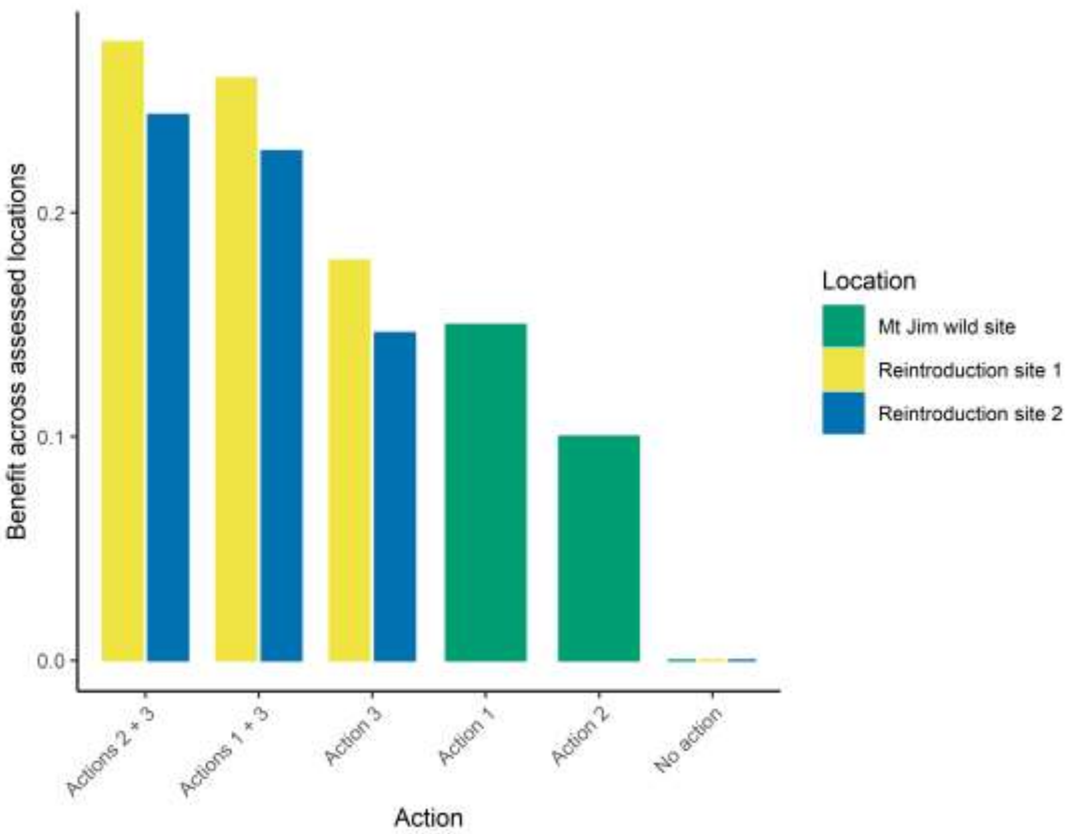

Figure 203. Benefit of each action/location combination to the *Kelleria bogongensis* overall persistence probability across all assessed locations.

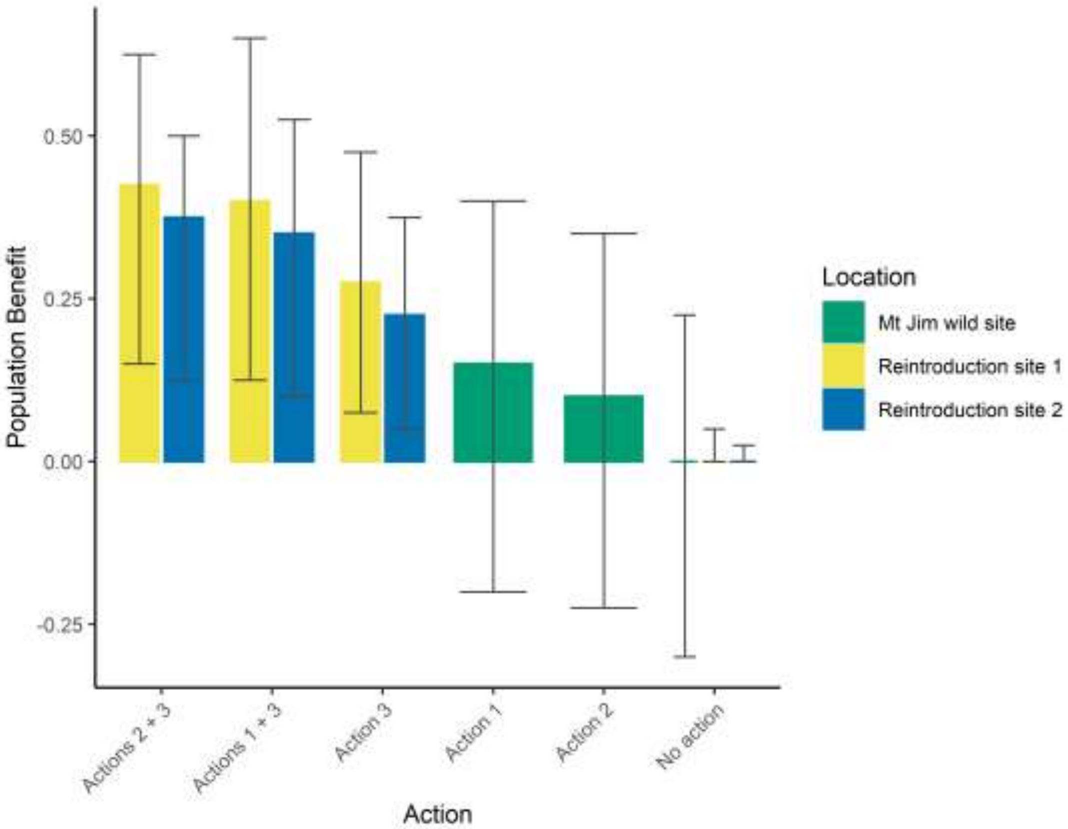

Figure 204. Mean change in *Kelleria bogongensis* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

In all cases, reintroduction to site 1 was rated as having a higher benefit to the probability of persistence compared to site 2, though both show a favourable effect. Fencing and herbivore control (action 1 & 2 respectively) shows a reasonable benefit to the existing wild population, as well as when applied complementarily to reintroduction.

Orchid species

Species: *Caladenia fulva*

Commonly known as Tawny spider-orchid. Endemic to Victoria, occurs in a small area near Stawell in the western goldfields region. This species is found in flat or gently sloping terrain on well drained soils, in woodlands and open forest dominated by *Eucalyptus leucoxylon* (yellow gum) and *E. tricarpa* (red ironbark). Threats and actions may be generalisable to a wider group of relatively less threatened understory taxa which occupy a similar niche.

Number of experts: 4

Location: Wild population Deep Lead NCR

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Herbivore control	Ongoing annual (5 days/year) control of feral herbivores (rabbits) and overabundant macropods (wallabies) within a radius of 3 km of the population by most effective available means.
2	Fencing	Fencing the majority of the population with a large (~0.5-1 ha) fence excluding all herbivores, with ongoing maintenance undertaken 1-2 years, opened occasionally for grazing in summer-autumn when necessary for biomass control.
3	Weed control	Ongoing weed control (5 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
4	Fire control	Burning of the population no more than once per 30 years.
5	Frequent fire	Burning of the population once per 10 years.
6	Reintroduction**	A reintroduction involves seed collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown plants, grown with their symbiotic mycorrhizal fungus, and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). For the purposes of this survey we have a fictional reintroduction site in an area of suitable habitat in Deep Lead NCR where *C. fulva does not currently occur* (i.e. similar quality to the wild site). Pollinators are confirmed to be present at the reintroduction site.

Based on expert assessment the benefit of each action at each location for this species is as follows:

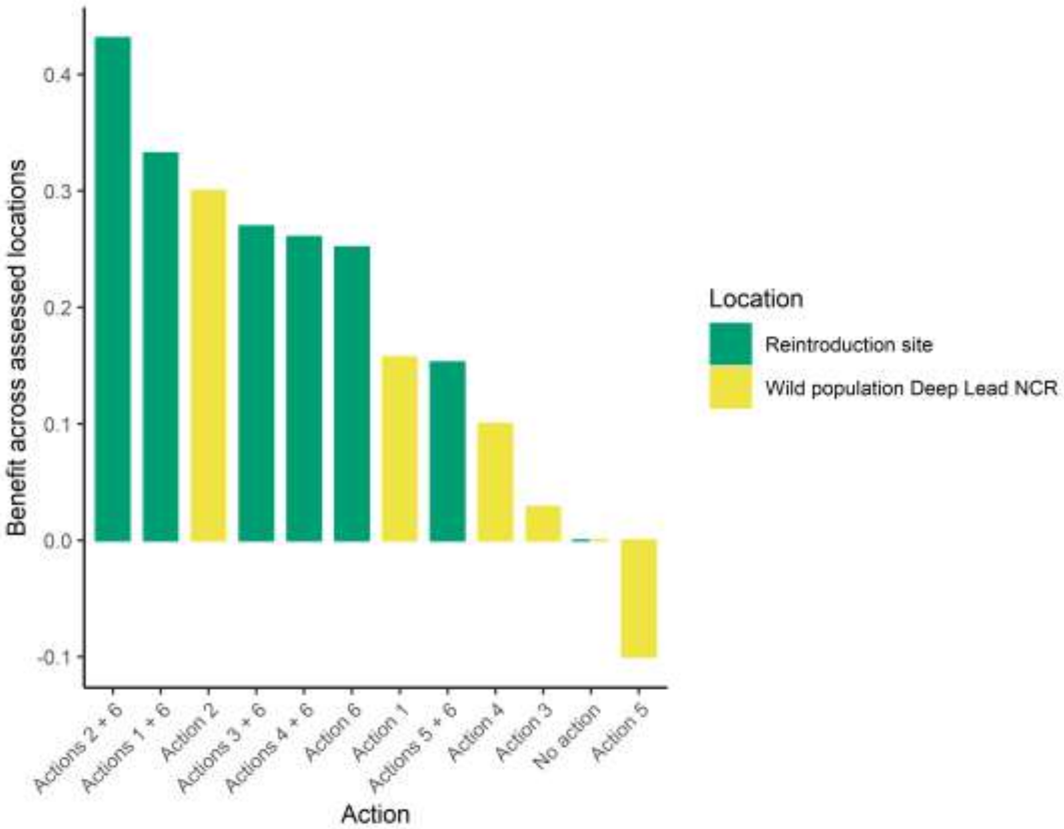

Figure 205. Benefit of each action/location combination to the *Caladenia fulva* overall persistence probability across all assessed locations.

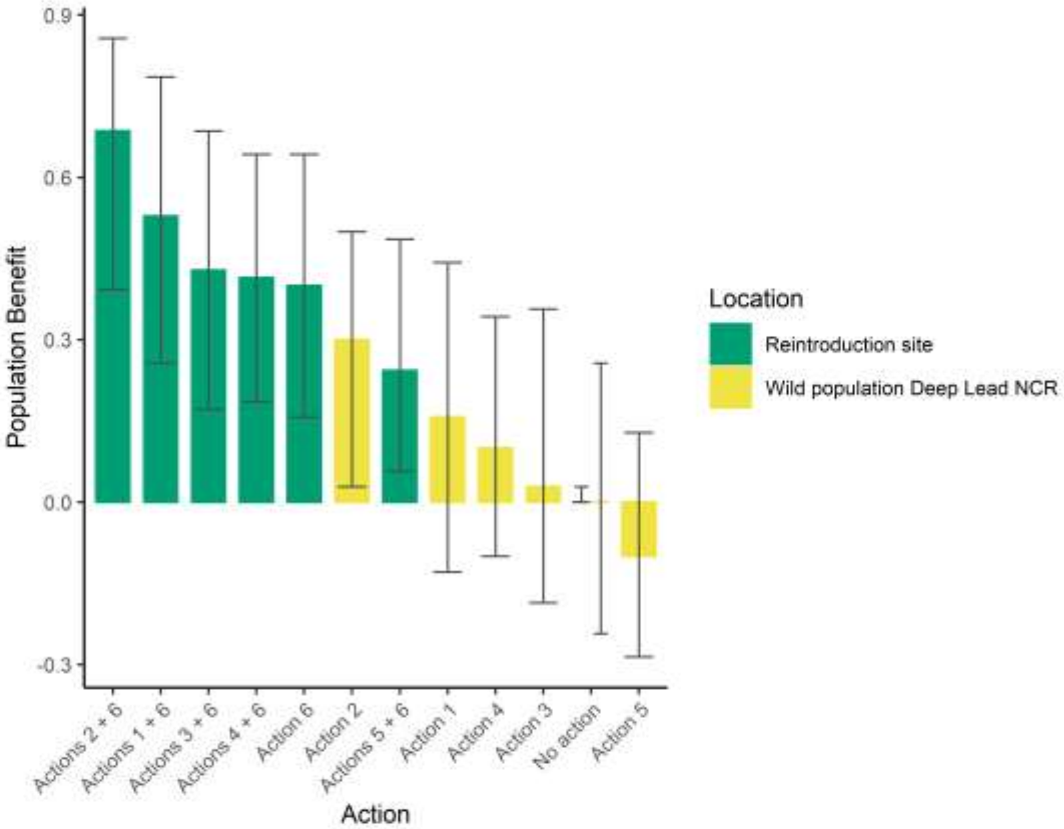

Figure 206. Mean change in *Caladenia fulva* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Results suggest that reintroduction (with complementary actions) would be most beneficial to the probability of persistence of this group. Fencing for herbivores would be greatly beneficial for the Deep Lead wild population, while burning every 10 years would have a notable disbenefit. Burning every 30 years appears to be the recommended fire regime.

Species: *Caladenia xanthochila*

Commonly known as Yellow-lip spider-orchid, grows to 30 cm, with a single leaf and greenish-yellow flower. In 2010, this species was known from two sites in north-western Victoria; one site contained an estimated 350 plants on private land near Murtoa and one site contained two plants on land managed by Parks Victoria near Inglewood. In 2000, three specimens were also collected north of Adelaide in the Flinders Ranges in South Australia. Flowering in the yellow-lip spider-orchid occurs in late August and September and is followed by summer dormancy. Threats and actions may be generalisable to a wider group of critically threatened woodland and dry forest understory taxa.

Number of experts: 3

Location: Wild population – Murtoa, Reintro site – Barabool NCR

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).

1	Herbivore control	Ongoing annual (5 days/year) control of feral herbivores (rabbits) and overabundant macropods within a radius of 5 km of the population by most effective available means.
2	Fencing	Fencing the majority of the population with a large (~0.5-1 ha) fence excluding all herbivores, with ongoing maintenance undertaken 1-2 years, never opened.
3	Fencing with biomass control	Biomass control through small prescribed burns conducted in Nov-Apr when required (e.g. every 5-10 years).
4	Weed control	Ongoing weed control (5 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
5	Fire control	Burning of the population no more than once per 30 years (as opposed to no restriction of prescribed burning frequency).
6	Reintroduction**	A reintroduction involves seed collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown plants, grown with their symbiotic mycorrhizal fungus, and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). For the purposes of this survey we have a reintroduction site in an area of suitable habitat in Barabool NCR where *C. xanthochila* does not currently occur (i.e. similar quality to the wild site). Pollinators are confirmed to be present at the reintroduction site

Based on expert assessment the benefit of each action at each location for this species is as follows:

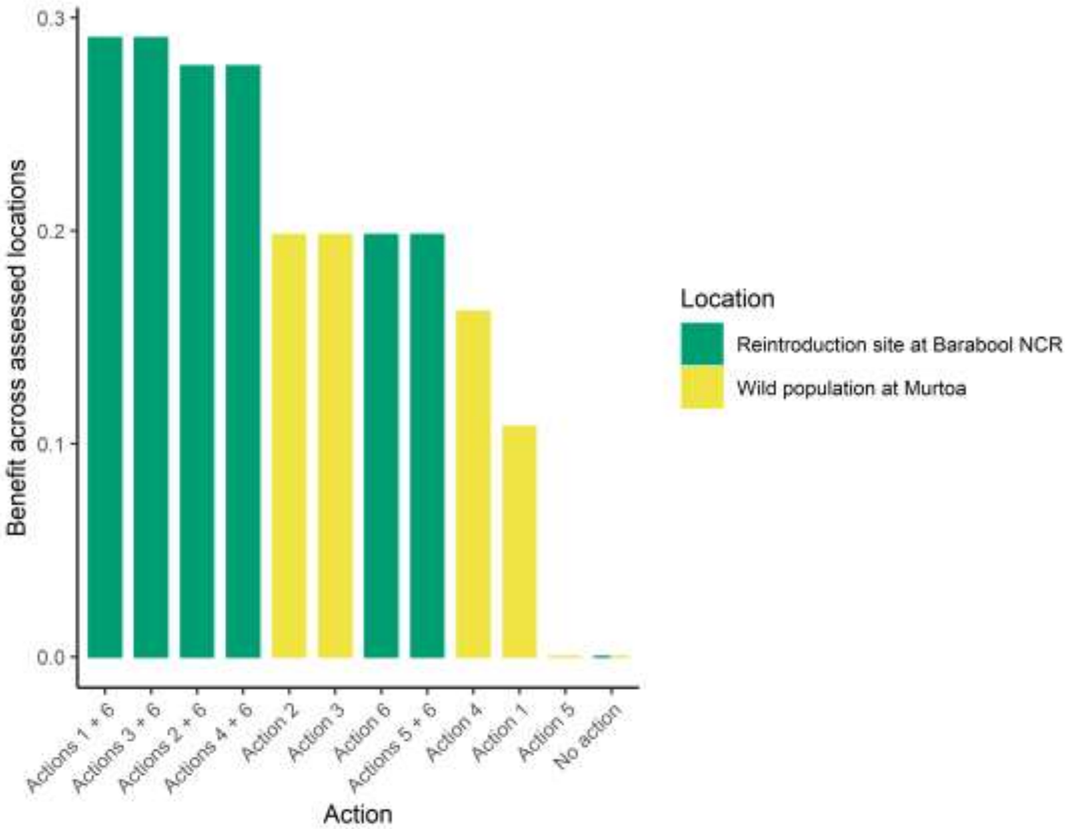

Figure 207. Benefit of each action/location combination to the *Caladenia xanthochila* overall persistence probability across all assessed locations.

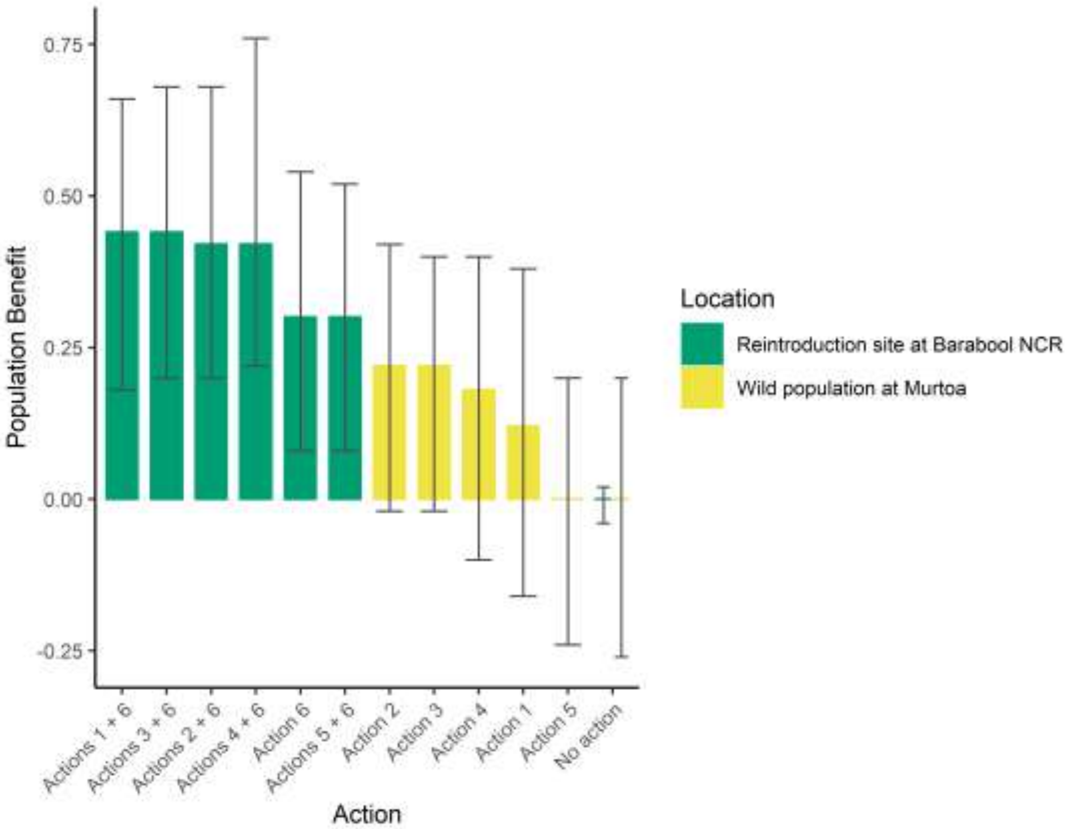

Figure 208. Mean change in *Caladenia xanthochila* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction (action 6) to Barabool NCR was assessed to be the most beneficial action for this species group, particularly when paired with complementary actions 1-5. For the wild population at Murtoa, permanent fencing for herbivores (action 2) was ranked highest.

Species: *Prasophyllum fosteri*

Commonly known as Shelford Leek-orchid, occurs in open species rich native grassland dominated by *Themeda triandra* with perennial herbs and lilies on poorly drained red-brown soil derived from basalt. Critical habitat has not been determined but fire or other disturbance such as slashing is highly likely to promote flowering. Threats and actions may be generalisable to a wider group of critically threatened grassland taxa.

Number of experts: 4

Location: Mt Mercer Shelford Rd wild site

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Weeds	Two days of post-fire control (i.e. every 2-4 years) of high-threat grassy and herbaceous weeds by a qualified and experienced operator.

1	Fire	Burning of the population(s) every 2-4 years in Nov-Apr.
2	Reintroduction**	One reintroduction would involve seed collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown plants, grown with their symbiotic mycorrhizal fungus. For the purposes of this survey we have three fictional reintroduction sites, the presence of pollinators is confirmed at all sites. ‘Reintroduction site 1’ is a protected public land reserve in the eastern Victorian Volcanic Plain within ~100 km of the wild population, reasonably large (>20 ha) and has reasonable-sized patches (>1 ha) of similar weed-free high quality native grassland to the wild site into which the plants are reintroduced; ‘Reintroduction site 2’ is a covenanted private land site in the eastern Victorian Volcanic Plain within ~100 km of the wild population, reasonably large (>20 ha) and has reasonable-sized patches (>1 ha) of similar weed-free high quality native grassland to the wild site into which the plants are reintroduced; and, ‘Reintroduction site 3’ is a small (1 ha) public land reserve (e.g. cemetery) also within ~100 km of the wild population and with high quality native grassland with no high threat weeds present.

Based on expert assessment the benefit of each action at each location for this species is as follows:

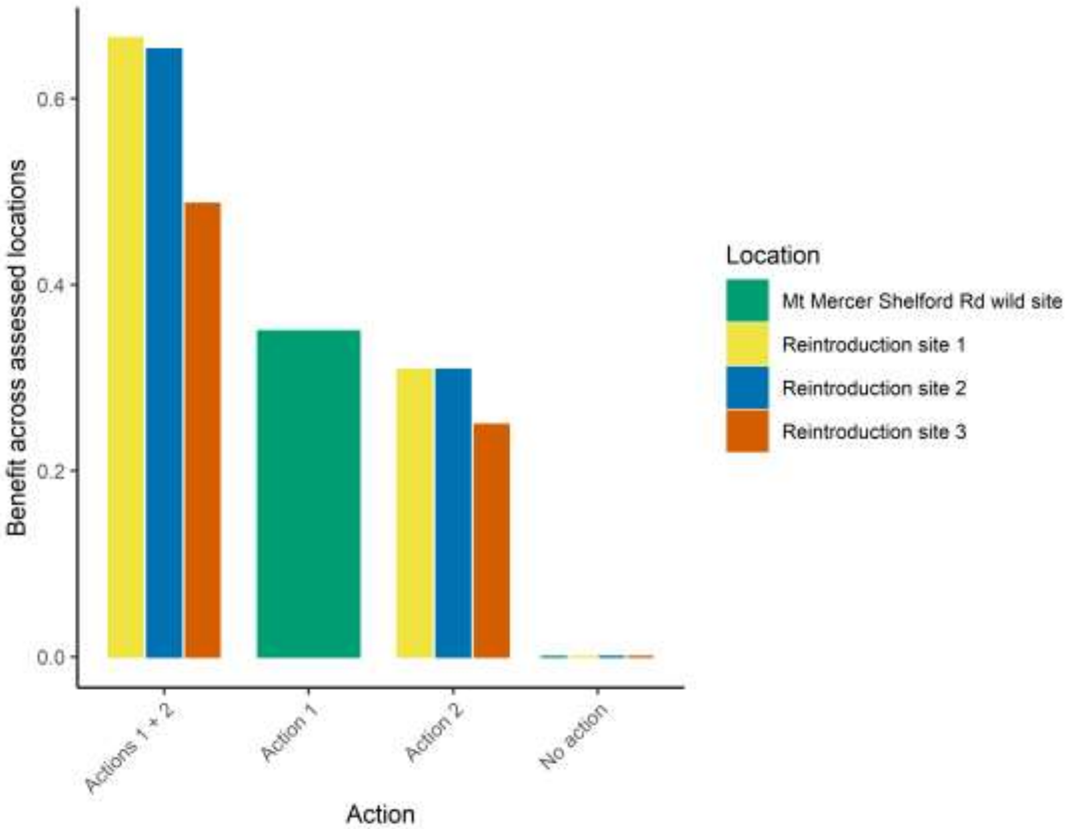

Figure 209. Benefit of each action/location combination to the *Prasophyllum fosteri* overall persistence probability across all assessed locations.

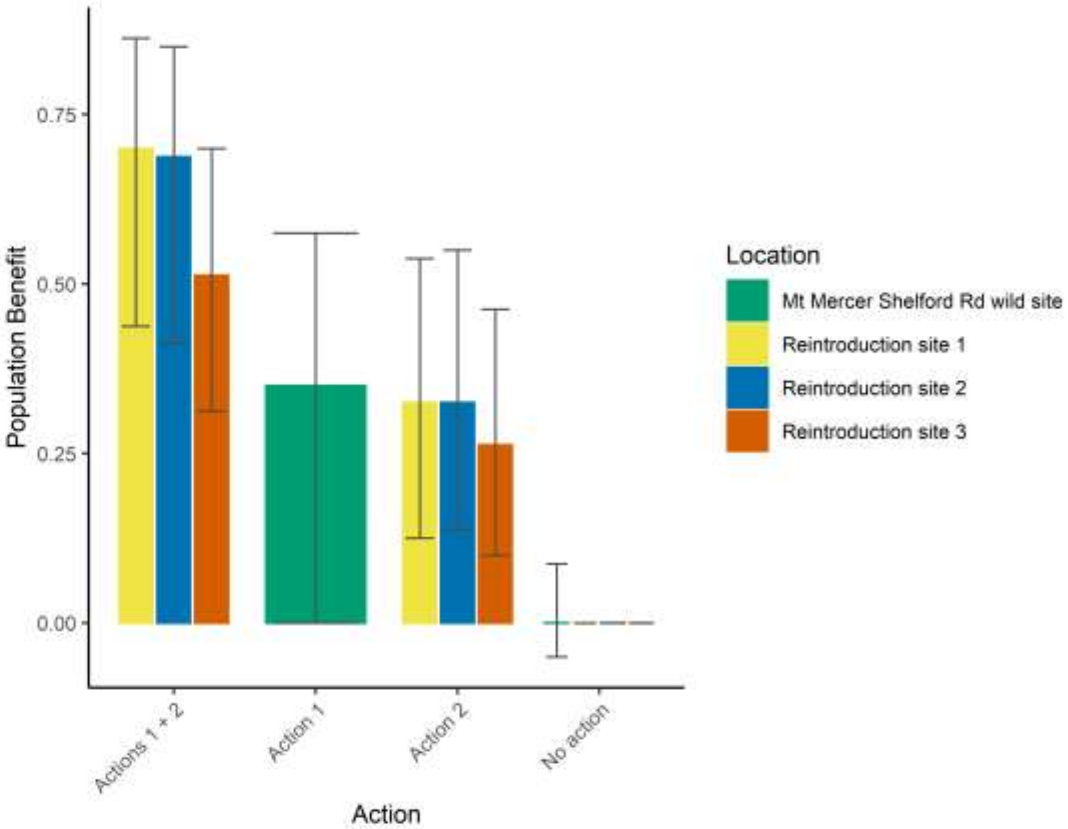

Figure 210. Mean change in *Prasophyllum fosteri* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Results suggest that sites 1 and 2 produce a similar benefit from reintroduction, with site 3 being less beneficial. Weed control and effective fire management (action 1) shows a notable benefit for the wild population and provides a boost to reintroduction.

Species: ***Prasophyllum niphopedium***

Commonly known as the Marsh Leek-orchid, is a species of orchid endemic to grassy alpine plains, sub-alpine meadows and fertile montane woodland in Victoria. It has a single tubular leaf and up to twenty greenish flowers with reddish markings. Threats and actions may be generalisable to a wider group of subalpine Sphagnum bog taxa.

Number of experts: 4

Location: Playgrounds wild population

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Feral Herbivore control	Ongoing annual (10 days/year) control of feral herbivores within a radius of 10 km of the population by most effective available means.
2	Fencing	Fencing the majority of the population with a large (~0.5-1 ha) fence excluding all herbivores, with ongoing maintenance undertaken 1-2 years, never opened due to threat from pigs.
3	Fencing with biomass control	Biomass control within the fenced area (as above) as required (e.g. every ~5ish years) by small prescribed burns.
4	Weeds	Ongoing annual weed control (10 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
5	Reintroduction**	A reintroduction involves seed collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown plants, grown with their symbiotic mycorrhizal fungus, and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). The fictional reintroduction site would be a site of similar habitat quality in the broader Cobberas area, but that is not currently known to be occupied by *P. niphopedium* (e.g. Native Dog Flat, upper Limestone Creek, Dead Horse Creek, etc.), with the most suitable site chosen based on a detailed assessment of the habitat. Pollinators are confirmed to be present.

Based on expert assessment the benefit of each action at each location for this species is as follows:

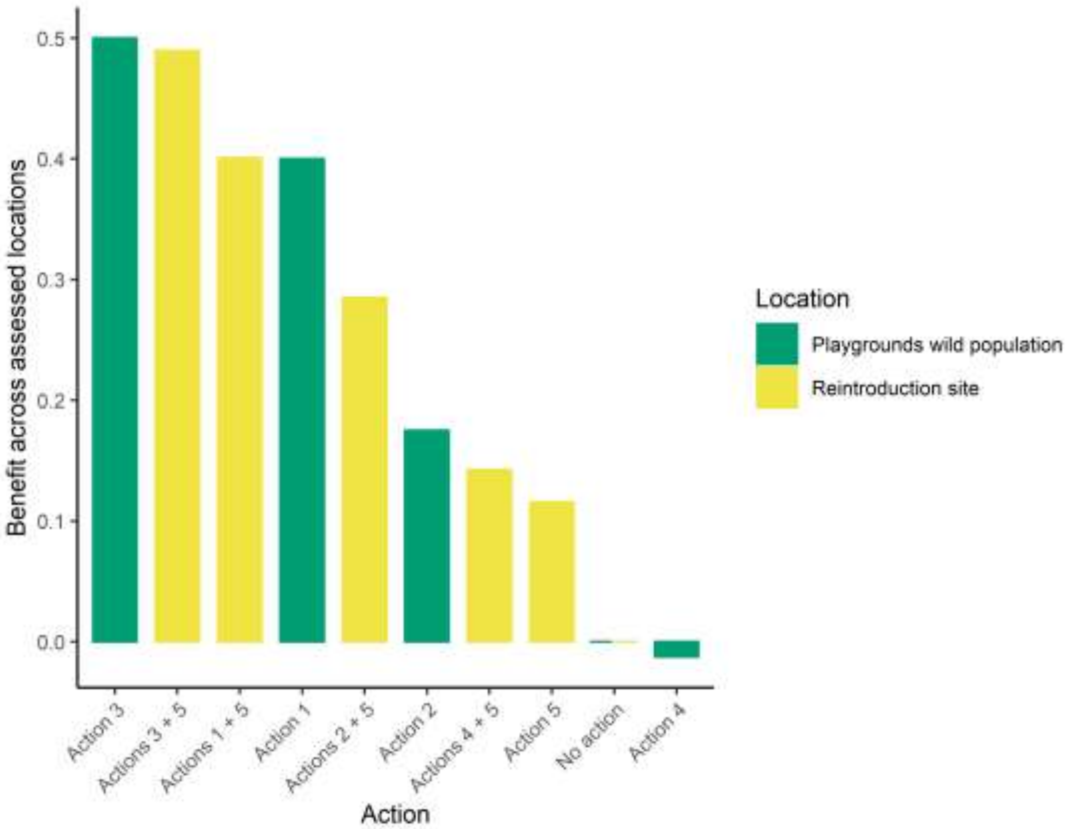

Figure 211. Benefit of each action/location combination to the *Prasophyllum niphopedium* overall persistence probability across all assessed locations.

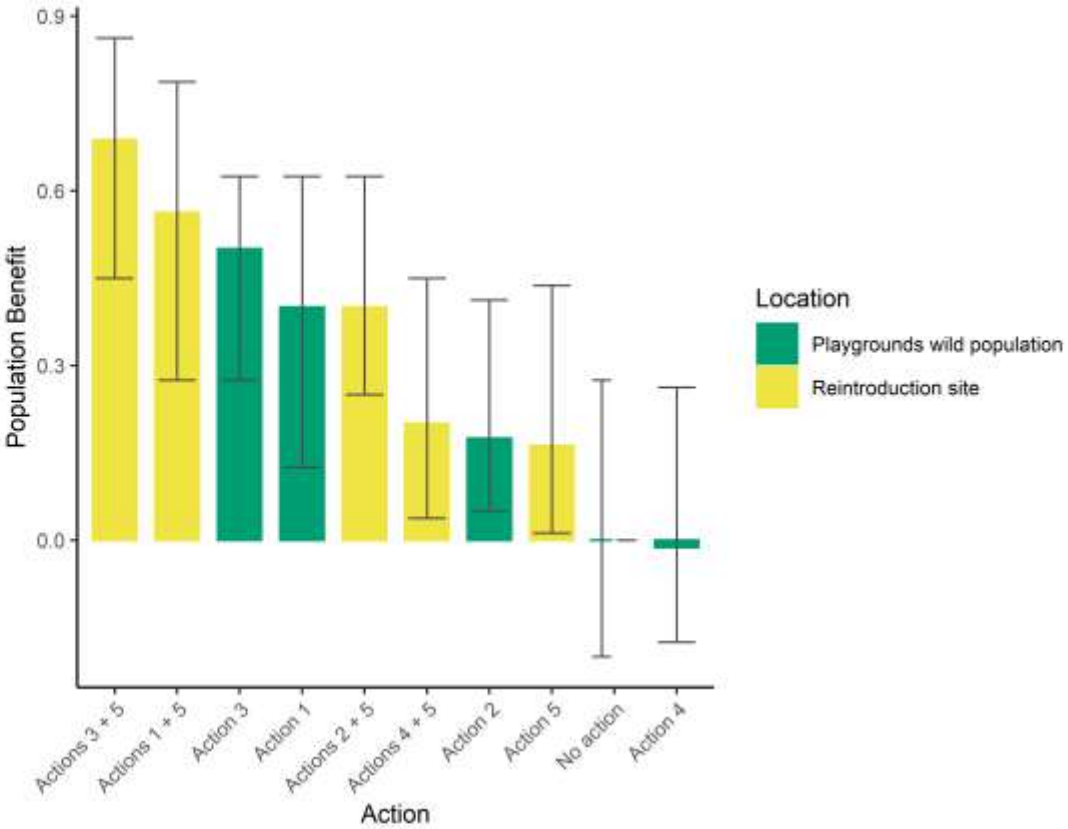

Figure 212. Mean change in *Prasophyllum niphopedium* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

The most beneficial action for this species is dependent on whether the focus is on either the landscape or location level. Across conditions, fencing with biomass control (action 3) either independently or in partnership with reintroduction (action 5) are rated as the most beneficial actions for this species group.

Species: *Prasophyllum uvidulum*

Commonly known as the Summer Leek-orchid. Known from a single locality near Shelley in north-eastern Victoria where found in moist seepage areas among grass in tall montane forest. *Prasophyllum uvidulum* is known from a single colony in winter-wet riparian grassland within shrubby *Eucalyptus dives* and *Eucalyptus viminalis* forest growing at about 750m altitude. Threats and actions may be generalisable to a wider group of critically threatened wetland taxa.

Number of experts: 5

Location: Pheasant Creek wild population

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Feral Herbivore control	Ongoing annual (10 days/year) control of feral herbivores within a radius of 20 km of the population by most effective available means.

2	Weeds	Ongoing annual weed control (10 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
3	Fencing	Fencing the majority of the population with a large deer-proof fence, but allowing in macropods, wombats and smaller herbivores, with installation of a hotwire for pigs to be used if required. Biomass is monitored and the fence opened if biomass becomes high. The fence is maintained on an ongoing basis.
4	Reintroduction**	One reintroduction involves seed collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown plants, grown with their symbiotic mycorrhizal fungus, and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). Pollinators are confirmed present at the reintro sites. For the purposes of this survey we have two fictional reintroduction sites. 'Reintroduction site 1' is a site of similar habitat quality in Pheasant Creek NCR. 'Reintroduction site 2' is a small area of similar habitat and quality in a larger forest block outside of Pheasant Creek NCR.

Based on expert assessment the benefit of each action at each location for this species is as follows:

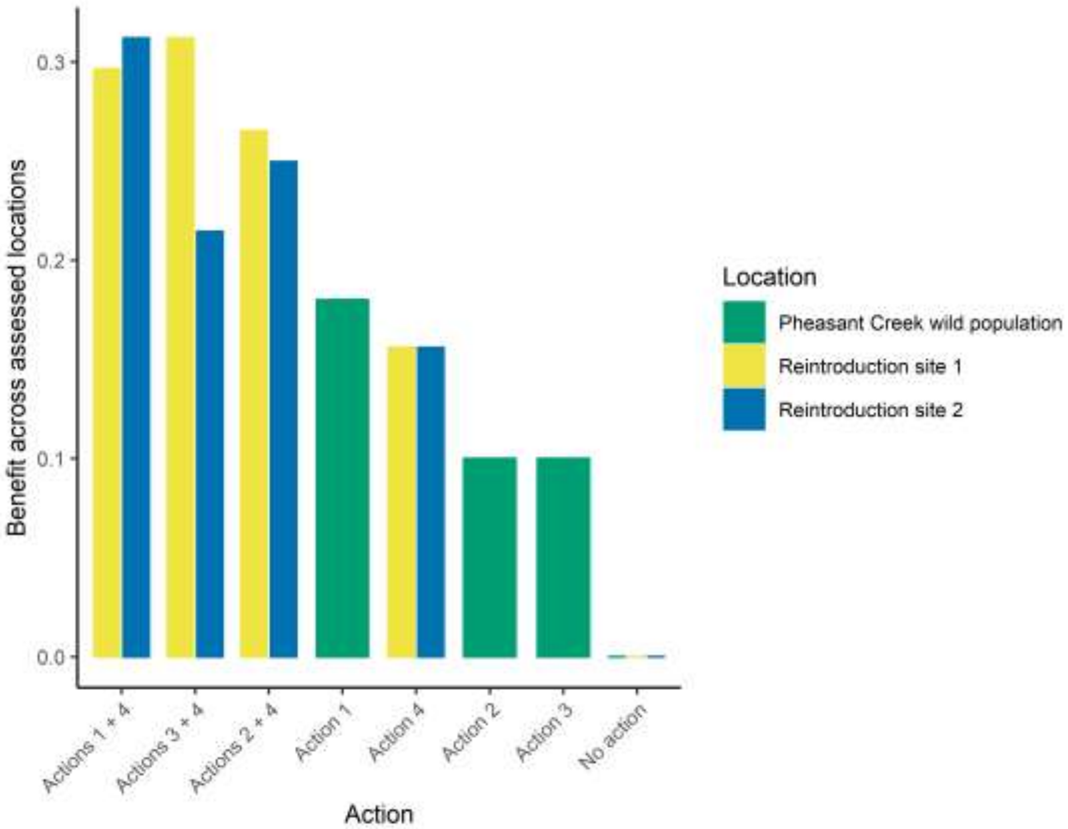

Figure 213. Benefit of each action/location combination to the *Prasophyllum uvidulum* overall persistence probability across all assessed locations.

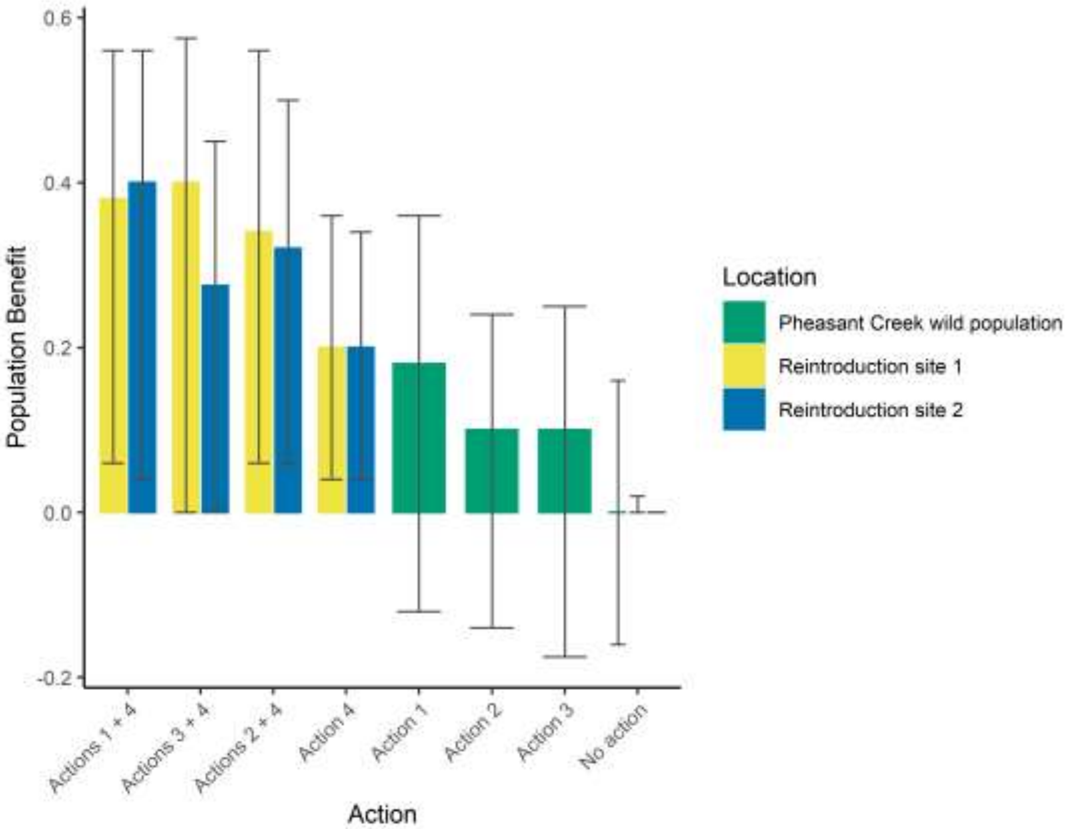

Figure 214. Mean change in *Prasophyllum uvidulum* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction to sites 1 or 2 appear to have a similar level of benefit to the species and fluctuate in rank depending on the additional complementary actions applied. Feral Herbivore control is the most beneficial action for the Pheasant Creed wild population.

Wetland species

Species: *Eriocaulon australasicum*

Commonly known as Austral or Southern Pipewort, grows in shallow, seasonally-inundated depressions and swamp margins on clay plains. Threats and actions may be generalisable to a wider group of critically threatened cryptic wetland annuals.

Number of experts: 2

Location: Wild population – Mereek NCR

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Herbivore control	Annual control (5 days/year) of feral herbivores and overabundant macropods within a radius of 5 km of the population by most effective available means.
2	Fencing	Fencing the majority of the population with a large (~0.5-1 ha) fence excluding all herbivores and people, with ongoing maintenance undertaken 1-2 years, opened to allow grazing by macropods when required.
3	Weed control	Ongoing weed control (5 days/year) of high-threat weeds (e.g *Acacia longifolia*) by a qualified and experienced operator.
4	Reintroduction**	A reintroduction involves seed collection from wild plants and propagation of 3000 ex-situ grown seedlings planted in three stages of 1000 plants each, over the course of 10-15 years (i.e. enabling some learning of microsite preference, etc). For the purposes of this survey we have a fictional reintroduction site in an area of suitable habitat in the Woohlpooer/Glenisla SF area, at a site where *E. australasicum* does not currently occur.

Based on expert assessment the benefit of each action at each location for this species is as follows:

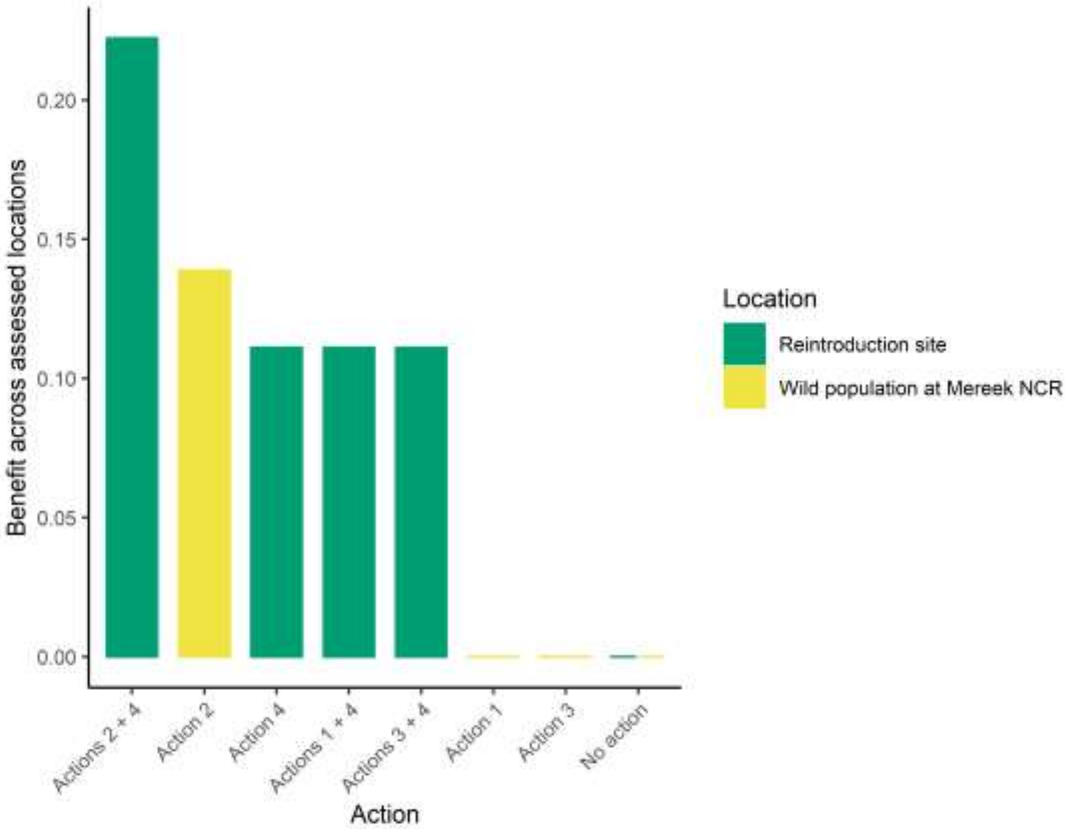

Figure 215. Benefit of each action/location combination to the *Eriocaulon australasicum* overall persistence probability across all assessed locations.

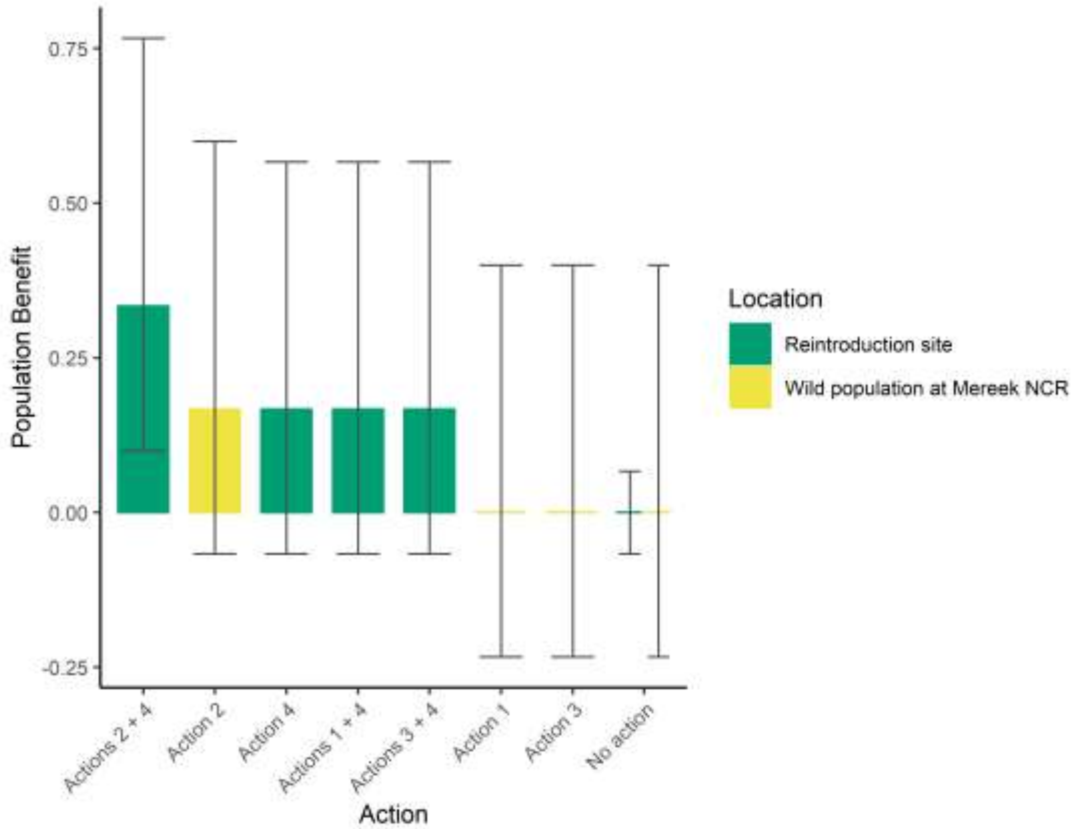

Figure 216. Mean change in *Eriocaulon australasicum* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction (action 4) with fencing (action 2) was ranked highest in terms of benefit for this species group. The addition of herbivore (action 1) or weed control (action 3) did not improve the outcome compared to reintroduction alone. For the wild population at Mereek, fencing was deemed the only action which would result in a benefit to the species group. Herbivore and weed control are therefore not considered beneficial in any case when conducted independently for this group.

Species: *Lobelia gelida*

Commonly known as Snow Pratia, a mat-forming, glabrous perennial; stems rooting at nodes. Known from shallow depressions that form pools following rain or snow-melt, and silty peats of stream margins in alpine heathlands on Mt Buffalo and Mt Reynard, north of Licola. Threats and actions may be generalisable to a wider group of relatively less threatened subalpine wetland taxa.

Number of experts: 6

Location: Mt Buffalo

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).

1	Fencing	Fencing of half the populations (Mt Buffalo = three populations fenced, Mt Reynard = half on the single population fenced) with several large, feral herbivore-proof fences, each with a minimum area of at least 0.25 ha. Fences would be permanently closed (i.e. not opened for periodic grazing) and have ongoing maintenance.
2	Feral Herbivore control	Ongoing, annual (10 days/year) control of all feral herbivores focused on radius of 20 km from wild populations by most effective available means.
3	Sediment removal	Remove sedimentation threats in Mt Buffalo.
4	Reintroduction**	One reintroduction involves seed collection from wild plants and propagation of 1000 1-2 yr old ex-situ grown plants. For the purposes of this survey we have two fictional reintroduction sites: 'Reintroduction site 1' is on Howitt High Plains and is a site of similar habitat quality to the wild populations, incorporating similar microsite variations to those that exist at the wild population. 'Reintroduction site 2' is also a site of similar habitat quality and microsite variation to the wild populations but is on the Bogong High Plains near the top of Cope Creek.

Based on expert assessment the benefit of each action at each location for this species is as follows:

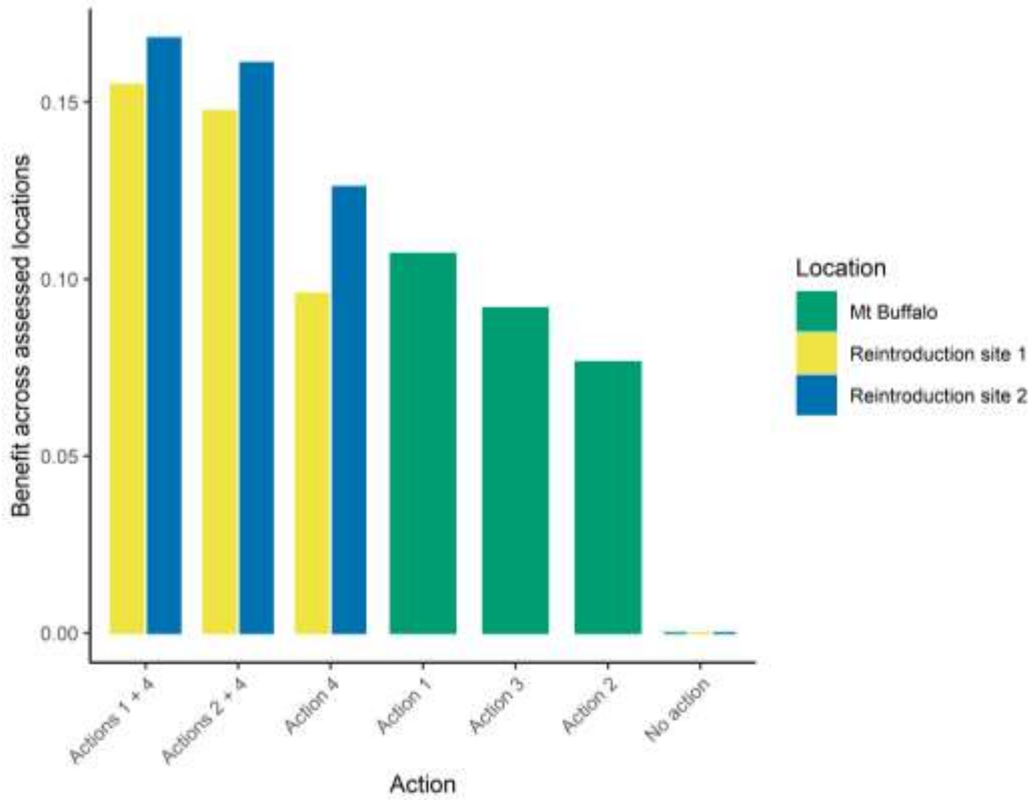

Figure 217. Benefit of each action/location combination to the *Lobelia gelida* overall persistence probability across all assessed locations.

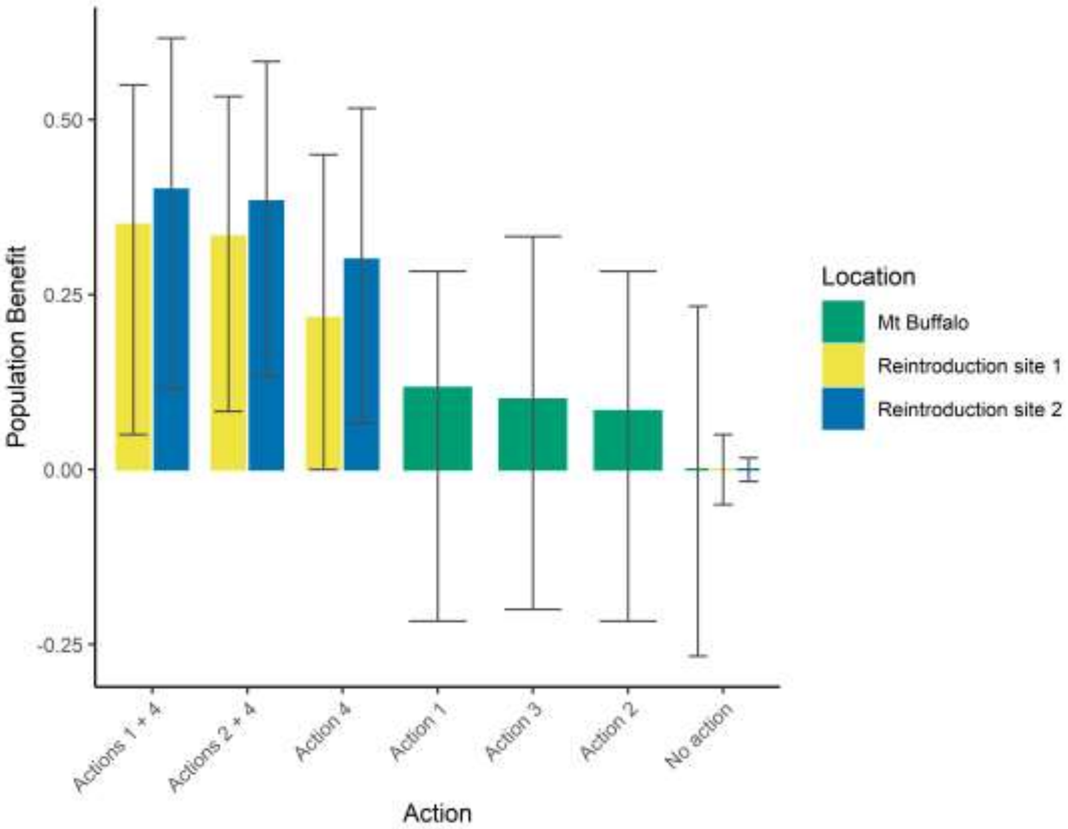

Figure 218. Mean change in *Lobelia gelida* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

In each case, reintroduction to site 2 was rated as having a higher benefit to the probability of persistence compared to site 3, though both show a favourable effect. Fencing and feral herbivore shows a reasonable benefit when applied complementarily to reintroduction. Each action at Mt Buffalo is rated quite highly, with fencing showing the greatest potential benefit, particularly when assessed across all locations.

Species: *Thelypteris confluens*

Commonly known as Marsh fern, particularly in its North American distribution. Rhizome creeping, slender and branched, growing tips covered in broad scales. Considered a wetland indicator species in Queensland, it is also found in a restricted distribution in north-east Victoria. Threats and actions may be generalisable to a wider group of relatively less threatened lowland wetland taxa.

 # experts: 2

Location: Dederang Gap private property

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Weeds	Ongoing annual weed control (5 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
2	Biomass control	Ongoing biomass control through slashing or grazing.
3	Reintroduction**	One reintroduction involves spore collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown plants and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). The reintroduction site is a private land site in the northeast matching the condition of the wild sites as closely as possible.

Based on expert assessment the benefit of each action at each location for this species is as follows:

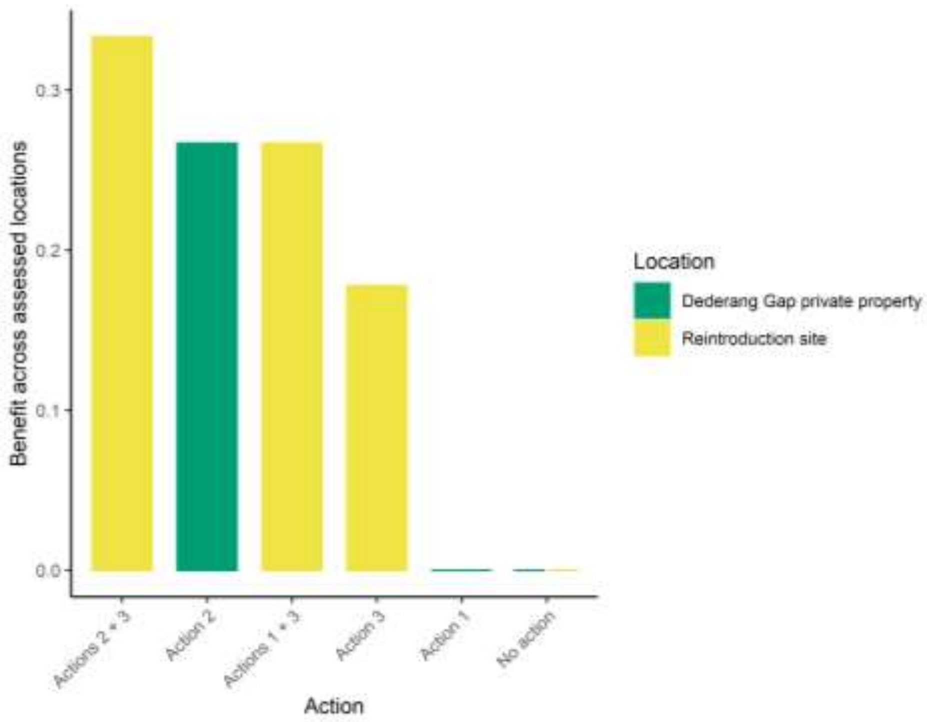

Figure 219. Benefit of each action/location combination to the *Thelypteris confluens* overall persistence probability across all assessed locations.

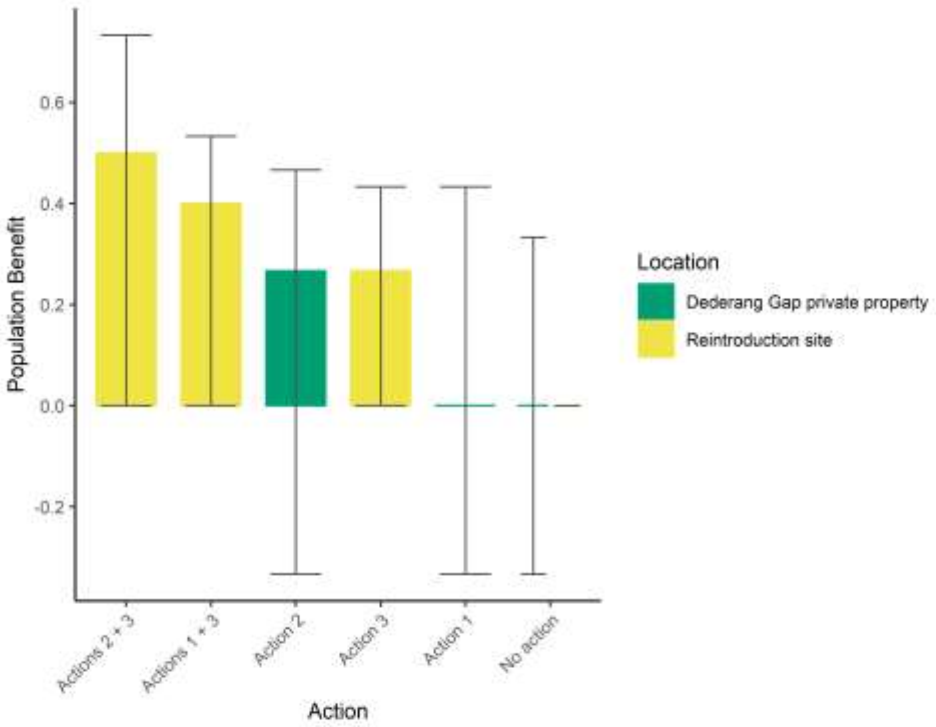

Figure 220. Mean change in *Thelypteris confluens* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction (action 3) is rated as the most beneficial action for this species group, particularly when paired with additional complementary actions. Biomass control (action 2) is the highest ranked action for the population at Dederang Gap, however it and weed control (action 1) have some potential for disbenefit in a worst-case scenario.

Shrub species

Species: *Grevillea celata*

Commonly known as Nowa Nowa Grevillea or Colquhoun Grevillea, a root-suckering shrub growing to 1.8 m tall. The species grows in an erect and open, or low and dense, form. The fruit is a leathery, hairy capsule with longitudinal ridges, which split to release winged seeds. Threats and actions may be generalisable to a wider group of relatively less threatened taxa which occupy a similar niche.

Number of experts: 7

Location: Watershed Road wild population

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Feral Herbivore control	Ongoing annual (10 days/year) control of feral herbivores within a radius of 10 km of the population by most effective available means.
2	Fencing	Fencing the majority of the population with a large (~0.5-1 ha) fence excluding all herbivores, with ongoing maintenance undertaken 1-2 years, never opened.
3	Weeds	Ongoing annual weed control (10 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
4	Fire management	Burnt no more than once per 15 years on average (by bushfires and prescribed burns).
5	Roadside signage	Poles/bollards at each end of population on the roadside and records of the population extent in DELWP databases.
6	Reintroduction**	Reintroduction involves seed collection from wild plants and propagation of 1000 ex-situ grown tubestock and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). The fictional reintroduction site would be a site of similar habitat quality to known wild populations in the Bruthen-Nowa Nowa area, but with no *Grevillea celata* plants present. It would not be near a roadside or firebreak. Plants would be initially caged with plastic/wire tree guards and watered monthly for the first summer following planting and monitored at regular intervals.

Based on expert assessment the benefit of each action at each location for this species is as follows:

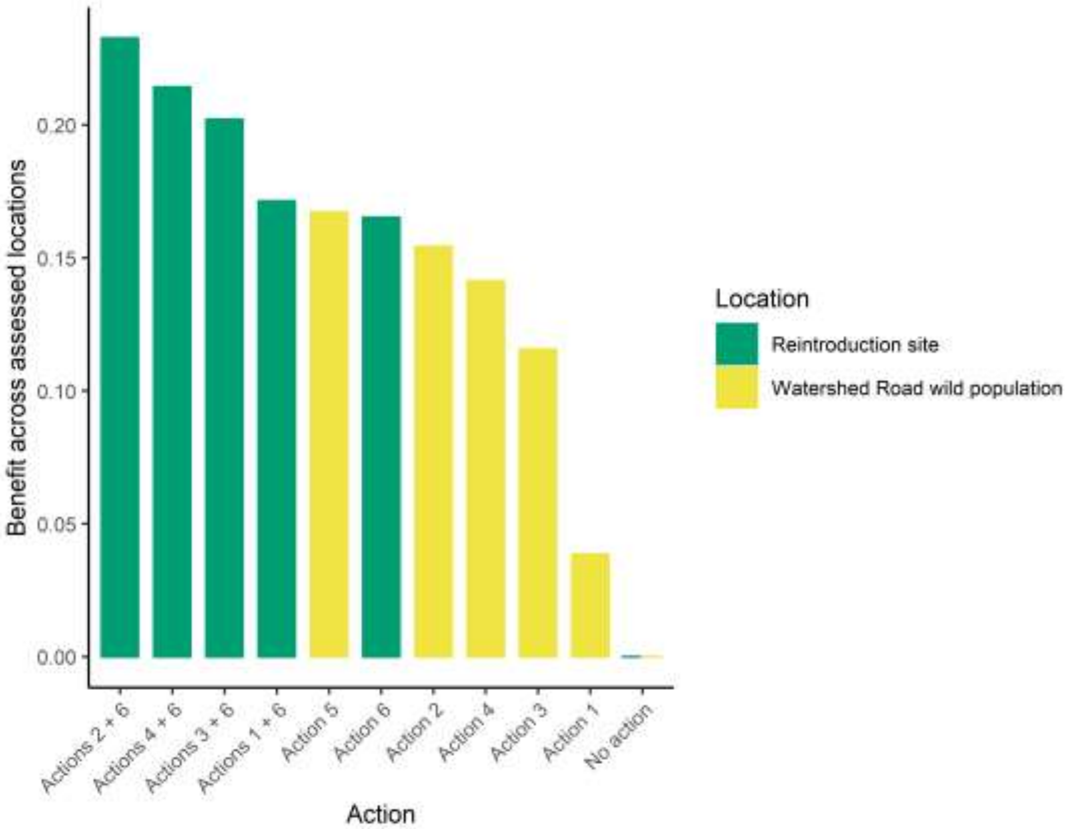

Figure 221. Benefit of each action/location combination to the *Grevillea celata* overall persistence probability across all assessed locations.

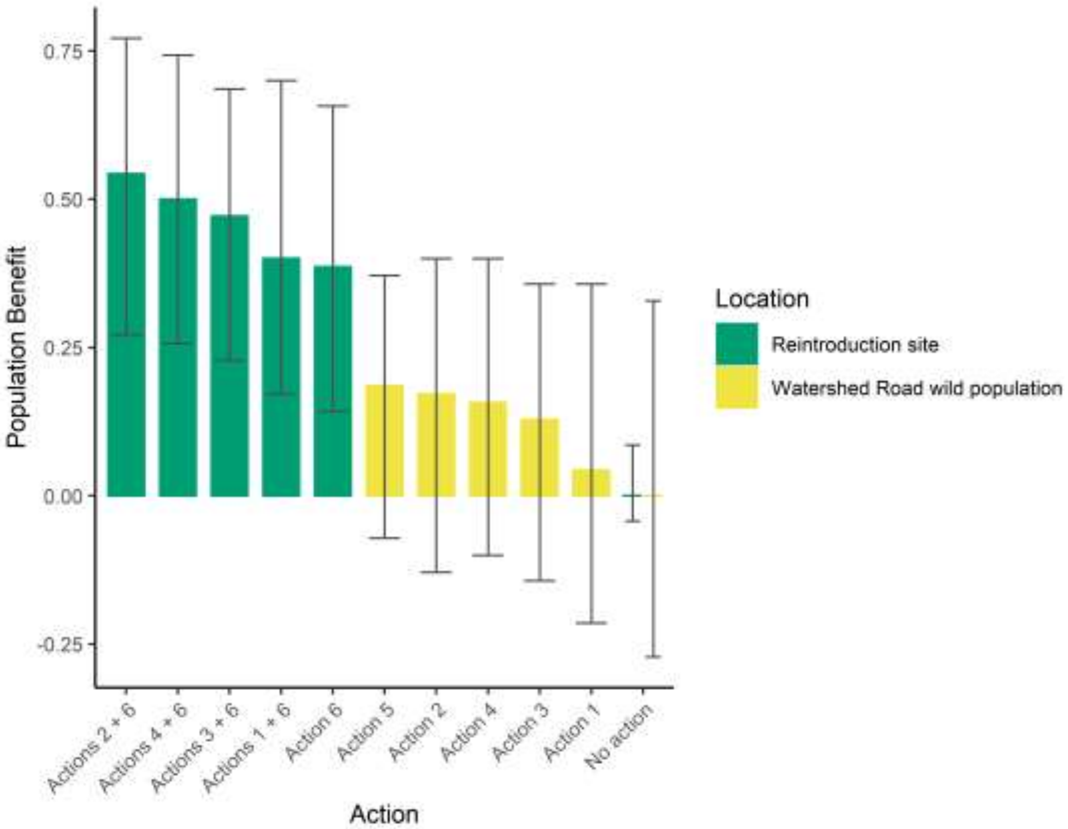

Figure 222. Mean change in *Grevillea celata* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction (action 6) was assessed to be the most beneficial action for this species group, particularly when paired with complementary actions (1-4). For the wild population at Watershed Road, roadside signage with population monitoring (action 5) was ranked highest.

Species: *Sphaerolobium acanthos*

Commonly known as Grampians Globe-pea, an erect wiry shrub confined to the Grampians and rare, recorded only from the Halls Gap-Mt William area and the Victoria Valley. Found in sclerophyll forest, woodland and heathland, usually near streams. Threats and actions may be generalisable to a wider group of pathogen-threatened shrubs.

Number of experts: 2

Location: Wild population - Mt William Rd

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Feral Herbivore control	Ongoing annual (5 days/year) control of feral herbivores (e.g. goats and deer) and overabundant macropods within a radius of 5 km of the population by most effective available means.

2	Fencing	Fencing the majority of the population with a large (~0.5-1 ha) fence excluding all herbivores, with ongoing maintenance undertaken 1-2 years, opened occasionally if biomass build-up is an issue. If a fence is not practical due to the terrain – plants caged with large (1 m^3) steel cages.
3	Fire	Burning of the population no more than once per 15 years (as opposed to no restriction of prescribed burning frequency). This includes bushfires (i.e. if there's a bushfire then no prescribed burn for at least 15 years, etc.).
4	Reintroduction**	A reintroduction involves seed collection from wild plants and propagation of 1000 mature (≥3 yo), ex-situ grown tubestock and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). For the purposes of this survey we have a fictional reintroduction site in an area of suitable habitat in Grampians/Gariwerd NP where *S. acanthos* does not currently occur (i.e. similar quality to the wild site) and where *Pc* is confirmed to be not present or at least not killing other sensitive species and at a low risk of introduction (e.g. not near walking or management tracks). Pollinators are confirmed to be present at the re-introduction site.

Based on expert assessment the benefit of each action at each location for this species is as follows:

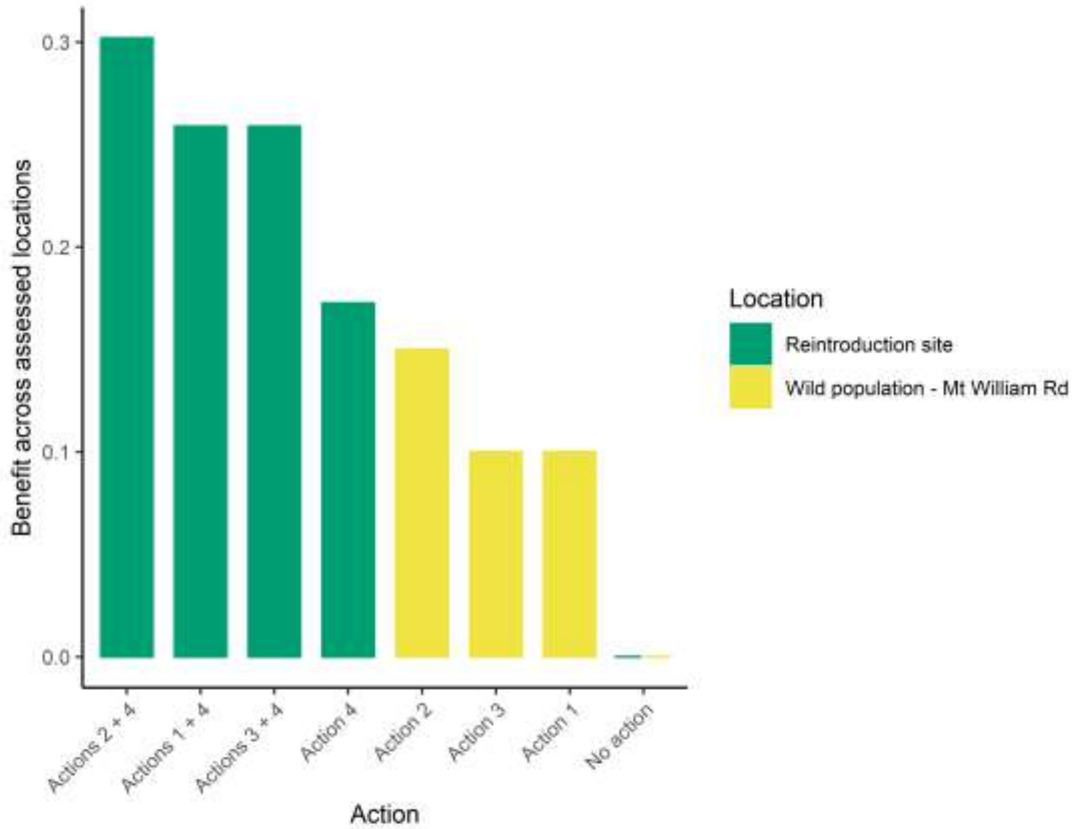

Figure 223. Benefit of each action/location combination to the *Sphaerolobium acanthos* overall persistence probability across all assessed locations.

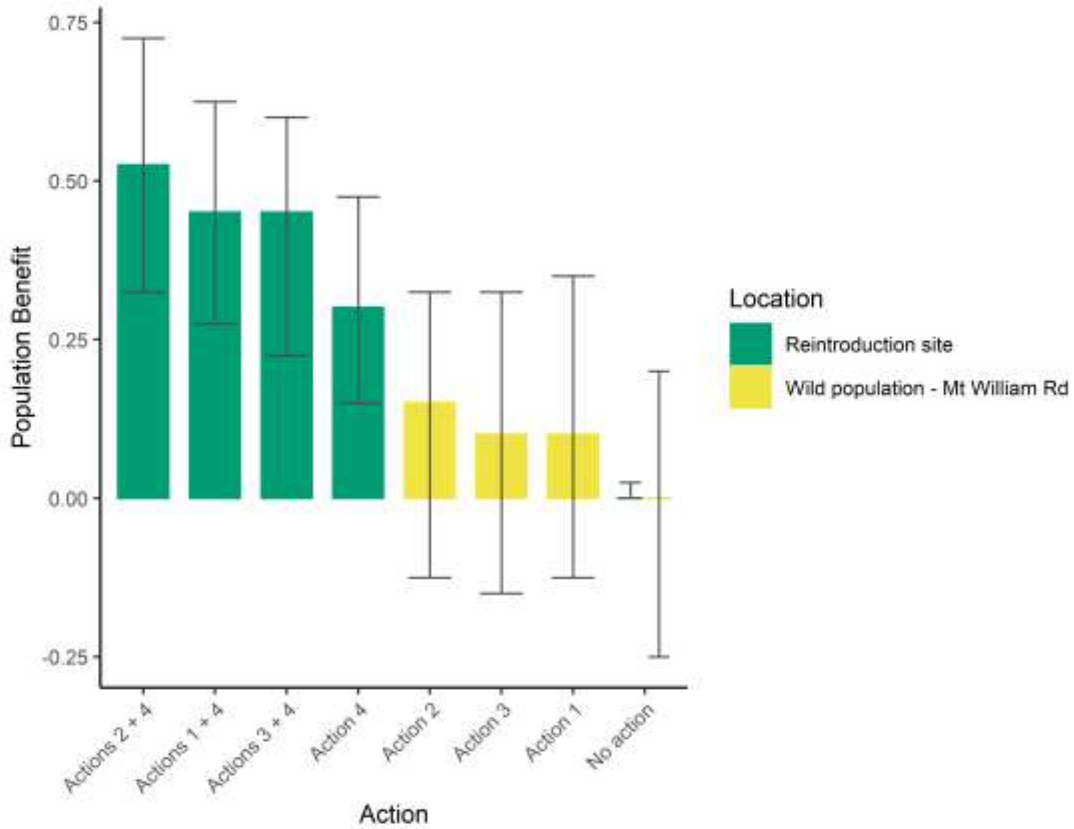

Figure 224. Mean change in *Sphaerolobium acanthos* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Reintroduction is rated as the most beneficial action for this species group, particularly when paired with additional complementary actions. Fencing for herbivores provides the greatest additional boost and is the most beneficial management action for the Mt William wild population.

Species: *Pomaderris subplicata*

Commonly known as Concave Pomaderris, an erect, multi-stemmed shrub that grows to 3 m high. Readily distinguished from all other NE Victorian Pomaderris species by its small ovate leaves that are more or less similarly hairy on both upper and lower surfaces. The species is known in the wild from only three localities, situated near Carboor Upper, approximately 40 km south east of Wangaratta in North East Victoria. The total remnant population is less than 90 plants covering 0.6ha. Threats and actions may be generalisable to a wider group of critically threatened taxa which occupy a similar niche.

Number of experts: 2

Location: Hancock Victorian Plantations (HVP) wild population

#	**Actions**:	
	No action	No management of the population or threats (any existing management ceases).

1	Feral Herbivore control	Ongoing annual (10 days/year) control of feral herbivores within a radius of 20 km of the population by most effective available means.
2	Weeds	Ongoing annual weed control (10 days/year) of high-threat weeds by a qualified and experienced operator in and around the population.
3	Fire	Limiting the number of prescribed burns to no more than one in a 50-year period. Note that bushfires may also occur.
4	Fencing	Fencing the majority of the population with a large deer-proof fence, but allowing in macropods, wombats and smaller herbivores. Biomass is monitored and the fence opened if biomass becomes high. The fence is maintained on an ongoing basis.
5	Reintroduction**	One reintroduction involves seed collection from wild plants and propagation of 1000 ex-situ grown tubestock and planted in three stages of 300-400 plants each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). For the purposes of this survey we have one fictional reintroduction site of similar habitat quality to the wild populations in Carboor area (i.e. the most suitable site based on current knowledge). Plants are watered for the first summer following planting.

Based on expert assessment the benefit of each action at each location for this species is as follows:

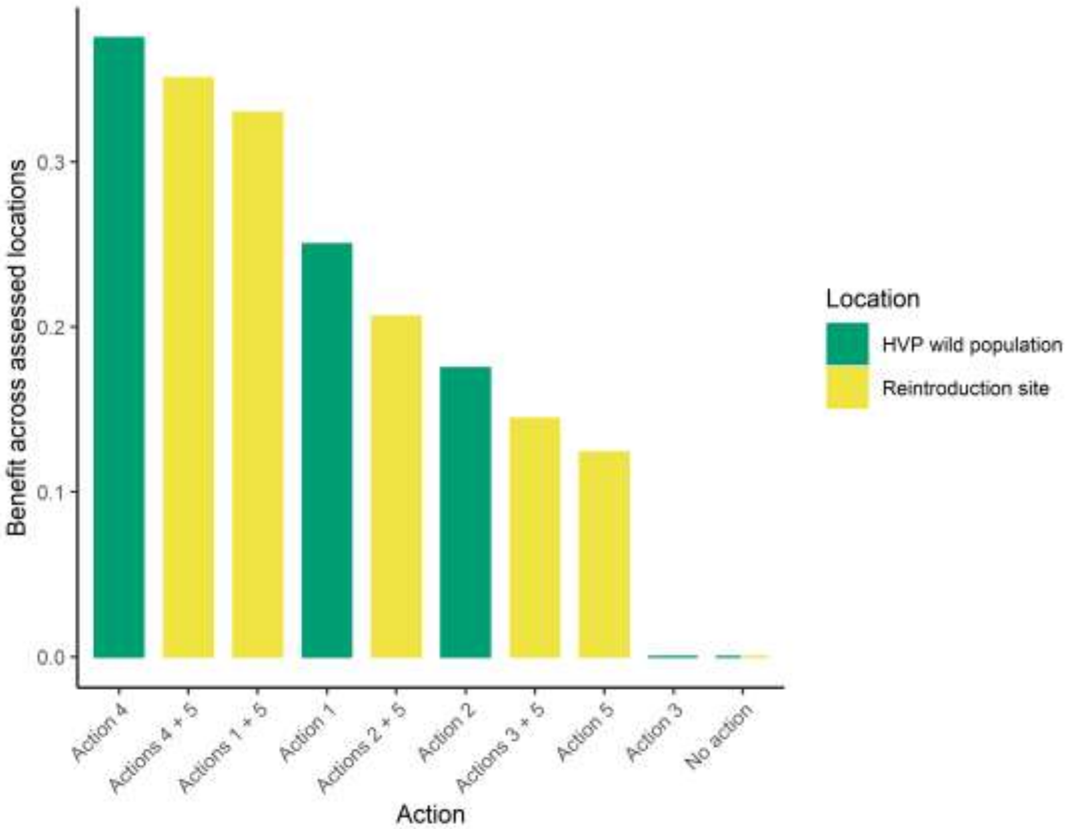

Figure 225. Benefit of each action/location combination to the *Pomaderris subplicata* overall persistence probability across all assessed locations.

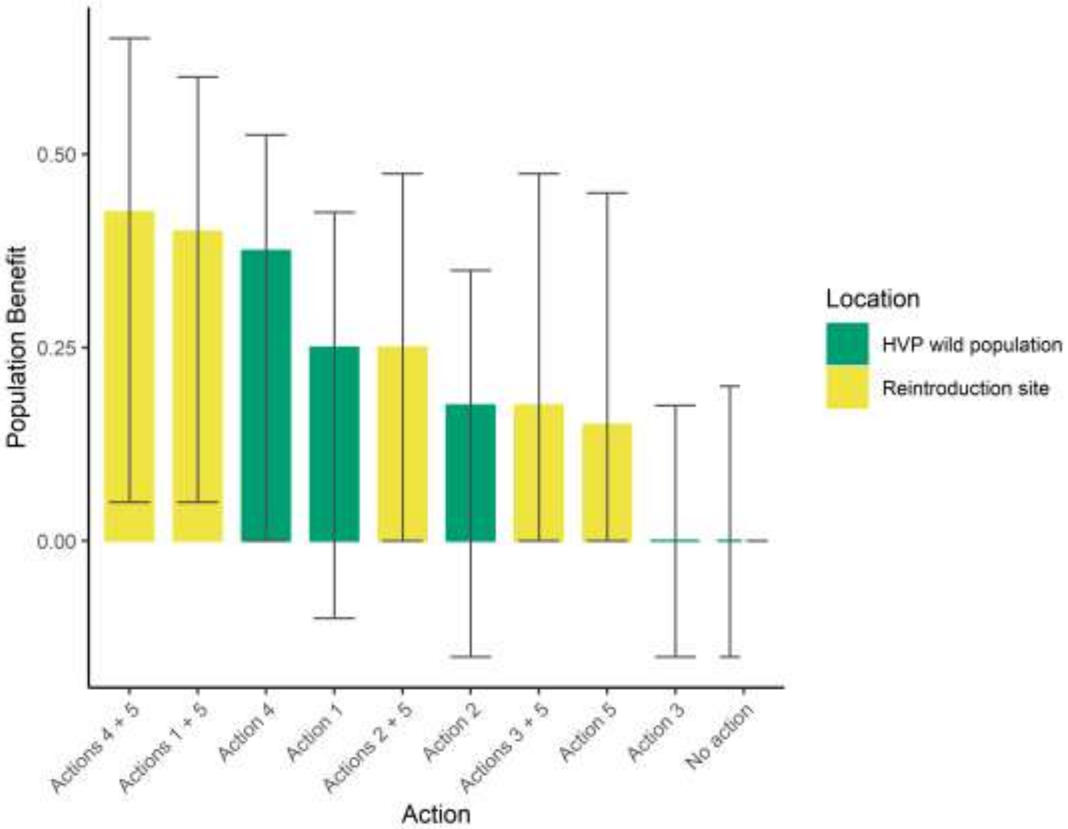

Figure 226. Mean change in *Pomaderris subplicata* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

The most beneficial action for this species is dependent on the location and whether the focus is on either the landscape or location level. Across conditions, fencing for deer (action 4) and/or reintroduction (action 5) are rated as highly beneficial actions for this species group.

Tree species

Species: *Eucalyptus alligatrix* subsp. *limaensis*

Commonly known as Lima Strngybark, a tree up to 30 m high, with rough bark persisting to small branches. Threats and actions may be generalisable to a wider group of narrow range endemic eucalypts.

Number of experts: 3

Location: Lima East Road wild population

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).
1	Feral Herbivore control	Effective fencing to prevent grazing/ringbarking by stock, and rabbit control in and around population if necessary.
2	Weeds	Ongoing annual weed control (5 days/year) of high-threat weeds by a qualified and experienced operator in and around the wild population.
3	Reintroduction**	One reintroduction involves seed collection from wild plants and propagation of 1000 tubestock, watered for the first summer and protected from stock. For the purposes of this survey we have two fictional reintroduction sites: ‘Reintroduction site 1’ is a degraded roadside currently devoid of native vegetation in the Lima-Swanpool area where *E. alligatrix* subsp. limaensis would have previously occurred. ‘Reintroduction site 2’ is a private property currently devoid of native vegetation in the Lima-Swanpool area where *E. alligatrix* subsp. limaensis would have previously occurred, with *E. alligatrix* subsp. limaensis planted as part of a farm revegetation or restoration project.

Based on expert assessment the benefit of each action at each location for this species is as follows:

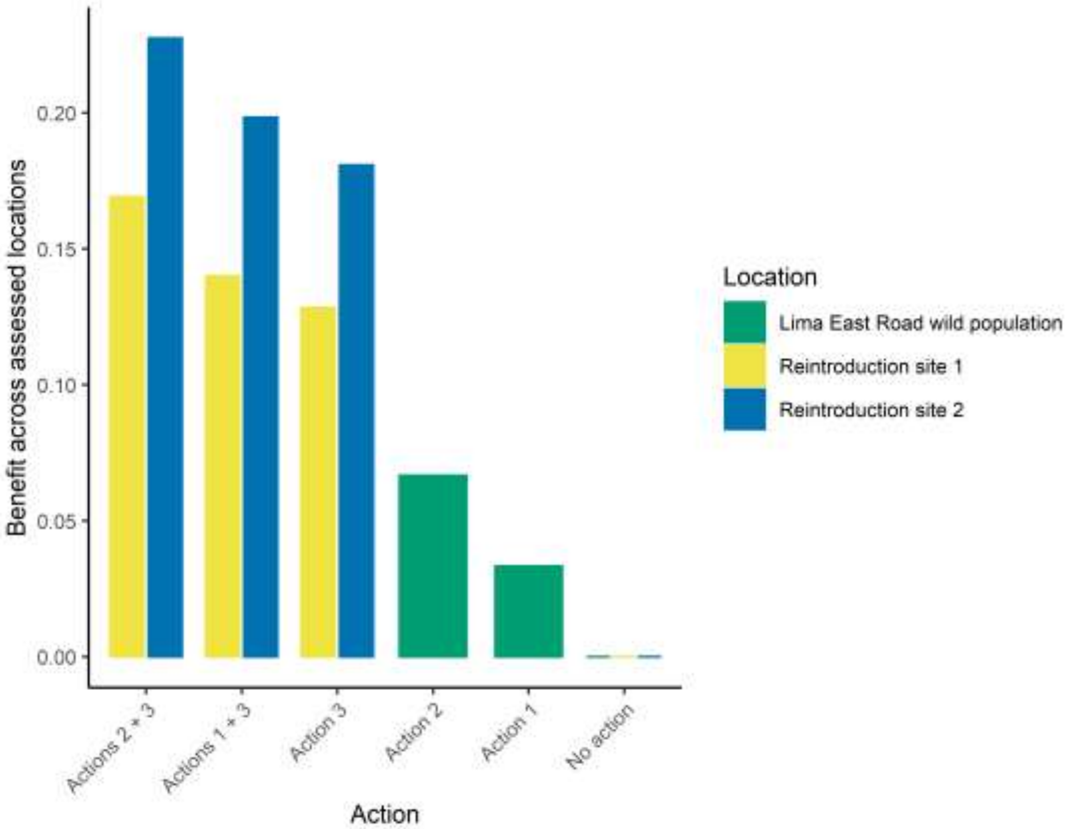

Figure 227. Benefit of each action/location combination to the *Eucalyptus alligatrix* subsp. *limaensis* overall persistence probability across all assessed locations.

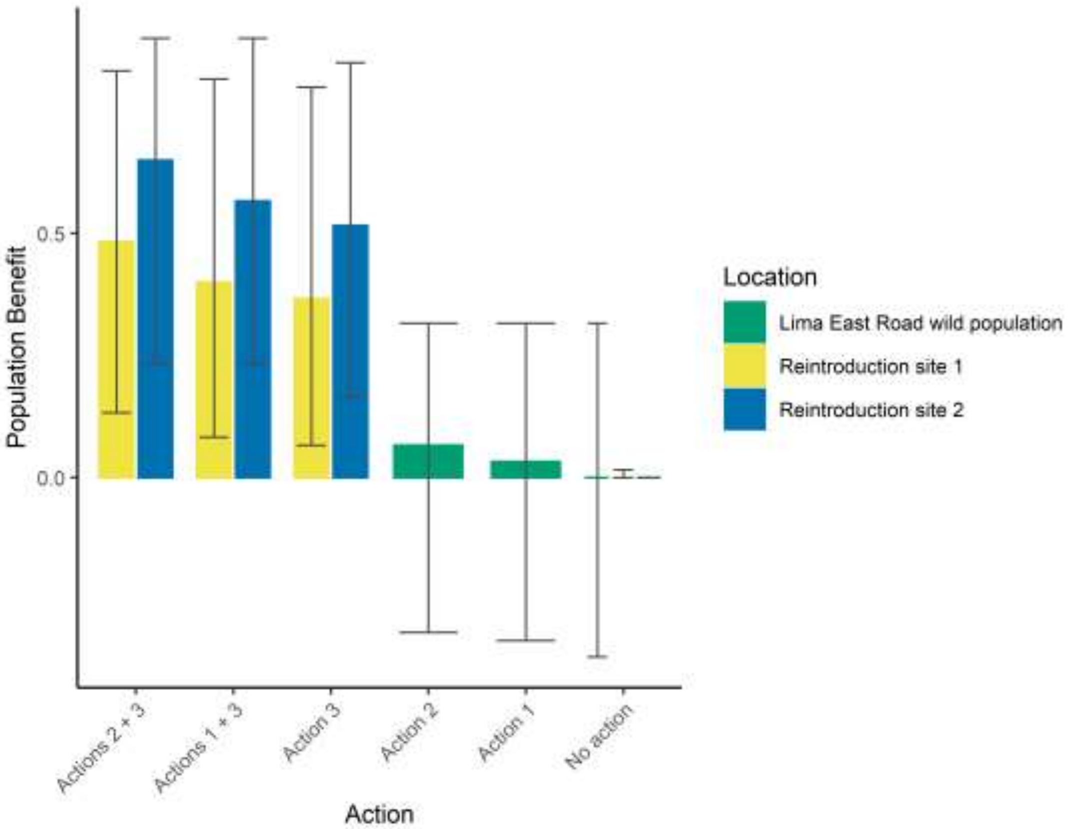

Figure 228. Mean change in *Eucalyptus alligatrix* subsp. *limaensis* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

In all cases, reintroduction to site 2 was rated as having a higher benefit to the probability of persistence compared to site 1, though both show a favourable effect. Herbivore and weed control in the existing wild population shows some benefit, though much less, and in the worst case, may result in some disbenefit.

Species: *Symplocos thwaitesii*

Commonly known as Buff Hazelwood, a small rainforest tree up to 20m tall. In Victoria there are only two known populations, both of which are adjacent to Wood Point, along the lower Snowy River in East Gippsland. Buff Hazelwood at both sites is confined to gullies containing warm temperate rainforest on metamorphosed sediments, such as slate and mudstone. Threats and actions may be generalisable to a wider group of fire-sensitive rainforest or wet forest taxa.

Number of experts: 5

Location: Woods Point unburnt wild site and Backbreak Creek wild site

#	Actions:	
	No action	No management of the population or threats (any existing management ceases).

1	Feral Herbivore control	Ongoing annual (10 days/year) control of feral herbivores within a radius of 10 km of the population by most effective available means.
2	Fencing	Fencing the majority of the population with several medium sized (e.g. ~20x20 m) fences that exclude all herbivores, with ongoing maintenance undertaken every year, fences are never opened.
3	Supplementation	Supplementation of the Backbreak Creek/Purple Patch (along the Snowy River) wild population that sustained significant losses of plants following the fire.
4	Supplementation with postfire weed control	Annual control (5 days/year for 10 years) of all high-threat weeds and eucalypt saplings in the burnt rainforest, and minimal control of overabundant native species (e.g. vines) around recovering *S. thwaitesii* if necessary, by a qualified and experienced operator.
5	Reintroduction**	A reintroduction involves seed/cutting collection from wild plants and propagation of 1000 ex-situ grown tube stock and planted in three stages of ~350 seedlings each, over the course of 5-10 years (i.e. enabling some learning of microsite preference, etc). Plants would be watered monthly for the first summer following planting if feasible and necessary. We have two fictional translocation sites: Creation of a new population in a similar (unburnt) warm-temperate rainforest site in East Gippsland where *S. thwaitesii* does not currently occur.

Based on expert assessment the benefit of each action at each location for this species is as follows:

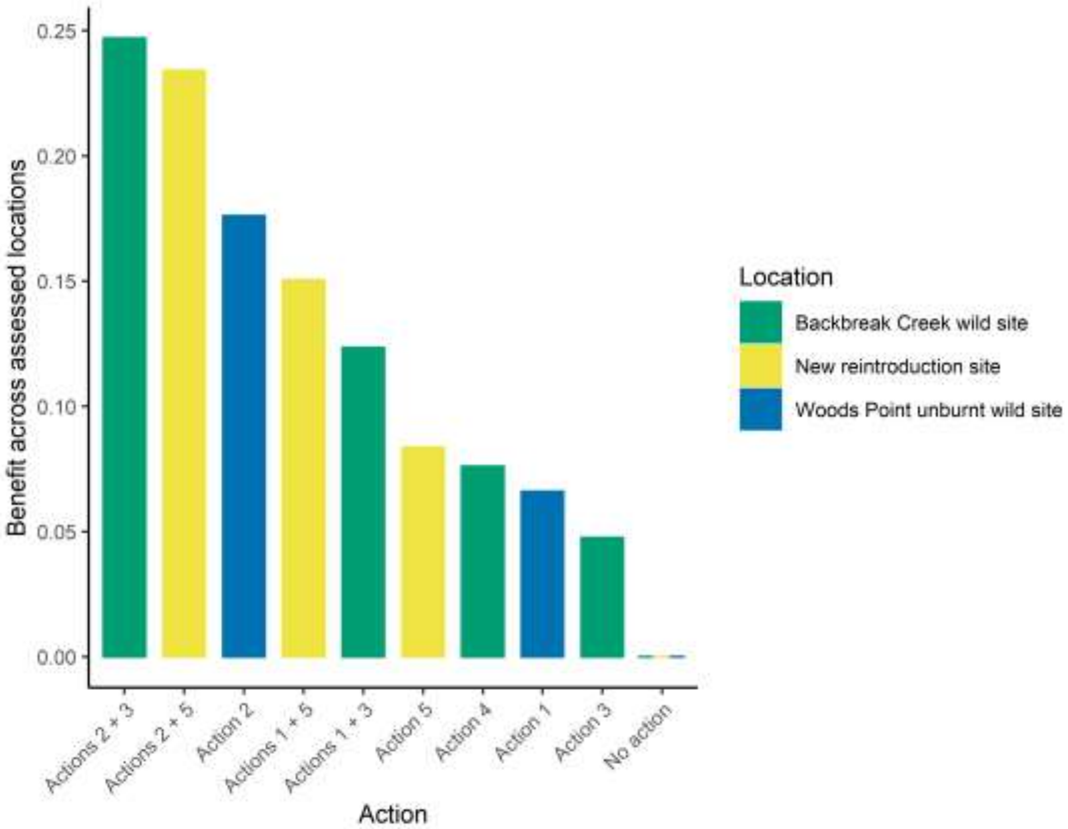

Figure 229. Benefit of each action/location combination to the *Symplocos thwaitesii* overall persistence probability across all assessed locations.

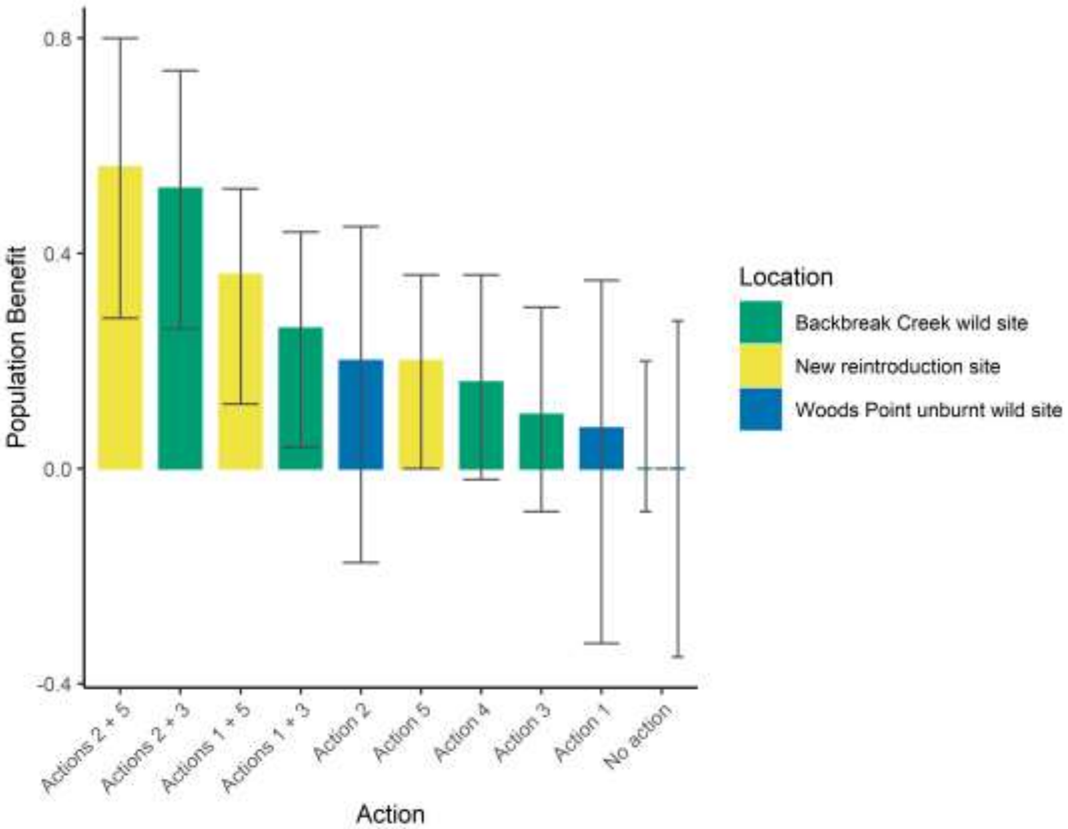

Figure 230. Mean change in *Symplocos thwaitesii* probability of persistence for each management action at each location. Error bars represent variation in expert estimates (mean upper to mean lower estimate).

Benefit from reintroduction (action 5) and supplementation (action 3) of this species is greatly improved by the addition of fencing (action 2). Fencing alone is the highest ranked individual action for the Woods Point wild site, highlighting the need to completely exclude herbivores to substantially improve probability of persistence.

Appendix 1. Supplementary reports

Some taxon leads chose to develop full reports outlining their methodology and decision making during this process. These were not explicitly required and so do not follow a consistent style. Other leads provided comparable detail through informal documentation and correspondence. These have been drawn on heavily in the detail provided in this report.

The following are available upon request:

- Bruce, M 2020. Biodiversity Bushfire Response: Taxon Group Specific Needs, Terrestrial Invertebrates. Arthur Rylah Institute for Environmental Research.
- Dell, M and Casanova, M 2020. Specific needs assessment to inform priorities to Maximise resilience in the landscape – bryophytes and freshwater algae. Dellbotany.
- Freestone, M 2020. Threatened Flora Part 1- Specific Needs Assessments and Causal Models. Royal Botanic Gardens Victoria.
- May, T 2021. Biodiversity Bushfire Response: Taxon Group Specific Needs -Fungi. Royal Botanic Gardens Victoria.
- Nelson, J, Cripps, J, Lumsden, L, Macak, P, Durkin, L, and Bush, A 2020. Biodiversity Bushfire Response: Taxon Group Workshops, Specific Needs Workshops for Arboreal Mammals, Owls and Bats. Arthur Rylah Institute for Environmental Research.
- Stoessel, D 2020. Biodiversity Bushfire Response Specific Needs: aquatic taxa. Arthur Rylah Institute for Environmental Research.

Appendix 2. Participants

Taxon group	Lead	Workshop participants	Expert elicitation respondents
Amphibians	Deon Gilbert (Zoos Victoria)	Deon Gilbert Jane Melville Joanne Sumner Nick Clemann Geoff Heard Glen Johnson David Hunter Jeremy Tscharke Don Driscoll Matt West	Damien Goodall Zack Atkins Matt West Peter Robertson Dave Hunter Nick Clemann
Aquatic species	Jian Yen & Daniel Stoessel (ARI)	Jarod Lyon Andrew Weeks Jeremy Hindell Kathryn Stanislawski Lauren Johnson Libby Rumpff Richard Marchant Tarmo Raadik	*9 additional experts who have chosen to remain anonymous*
Arboreal mammals, owls, and bats	Jenny Nelson (ARI)	Jenny Nelson Daniel Pendavingh Jerry Alexander Lindy Lumsden Louise Durkin Phoebe Macak Stephen Henry	Jerry Alexander Lindy Lumsden Steve Henry Richard Hill Dan Pendavingh Benjamin Wagner William Terry Adam Whitchurch Charlie Pascoe Drew Liepa Brad Blake Bert Lobert Rodney van der Ree Rohan Bilney Richard Loyn Ed McNabb Mark Antos Yvonne Ingeme Tony Mitchell Marc Perri

			Amanda Bush Terry Reardon Brad Law Leroy Gonsalves Michael Pennay Doug Mills
Birds (excluding owls)	Dan Pendavingh (DELWP Hume region)	Daniel Pendavingh Jenny Lau Karen Rowe Katherine Selwood Mark Antos Michael Magrath Peter Menkhorst Richard Hill Rohan Clarke Simon Watson	Mark Antos Peter Menkhorst Simon Watson Richard Hill Mick Bramwell Marc Perri Simon Verdon Dan Pendavingh Jenny Lau Karen Rowe
Bryophytes and algae	Matt Dell (Dellbotany)	*Independent workshop conducted prior to this project. For details see:* *Dell M, Worley M, Casanova MT, McMullan-Fisher S, Louwhoff S and Fielder J (2020) An assessment of conservation priorities and actions for bryophytes, algae and fungi in response to Victoria's 2019–2020 bushfires. Independent consultant report, Melbourne, Victoria.*	Juliet Brodie Michelle Casanova Tim Entwisle Maria Gibson Niels Klazenga Glenn McGregor Dale Tonkinson Perpetua Turner Jo Wilbraham Marianne Worley
Critical-weight-range mammals and macropods	Sakib Kazi (Parks Victoria)	Sakib Kazi Alan Robley Amy Coetsee Andrew Murray Bronwyn Hradsky Charlie Pascoe Dan Harley Euan Ritchie Jack Pascoe Jemma Cripps Jerry Alexander Marissa Parrot Naomi Davis	Dan Harley Jack Pascoe Jerry Alexander Marissa Parrot Naomi Davis Richard Hill Jenny Nelson Lindy Lumsden Marc Perri Phoebe Burns John Woinarksi Phoebe Macak Garry Peterson

		Peter Menkhorst Richard Hill	
Fungi	Tom May (Royal Botanic Gardens)	Tom May Ema Corro Michael Amor Sapphire McMullan-Fisher Bryony Horton Teresa Lebel Susan Nuske Melvin Xu Patrick Leonard Matt Barrett Caine Barlow Richard Robinson	Michael Amor Sapphire McMullan-Fisher Tom May Matt Dell Julie Fielder Richard Robinson Naveed Davoodain
Invertebrate functional groups	Matt Bruce (ARI)	Matt Bruce Adnan Moussalli David Bryant Diane Crowther Don Driscoll Heloise Gibb James Dorey Jess Marsh John Woinarski Karly Learmonth Kate Pearce Kate Umbers Kathryn Schneider Ken Walker Martin Steinbauer Michael Kearney Michael Magrath Nick Murphy Nick Porch Richard Marchant Ross Field Susan Taylor	Beverly Van Praagh Susan Taylor Greg Hollis Adnan Moussalli Di Crowther Richard Marchant Julia Mynott David Bryant
Native rodents and small marsupials	Kevin Rowe (Museums Victoria)	Kevin Rowe Anna Moodie Charlie Pascoe Dale Nimmo Dan Harley Jenny Nelson Jerry Alexander	Andrew Bennett Anna Moodie Ben Holmes Charlie Pascoe Dale Nimmo Dave Watson Derek Sandow

		Marissa Parrot Naomi Davis Peter Menkhorst Phoebe Macak Richard Hill Sakib Kazi Simon Watson Timothy Doherty	Desley Whisson Helen Waudby Jenny Nelson Jerry Alexander Jim Whelan Karen Rowe Luke Kelly Marissa Parrott Matt Swan Naomi Davis Peter Homan Peter Menkhorst Phoebe Burns Phoebe Macak Richard Hill Simon Watson Terry Coates Timothy Doherty
Reptiles	Nick Clemann (ARI)	Nick Clemann Dale Nimmo Dale Tonkinson David Hunter Deon Gilbert Garry Peterson Geoff Heard Jane Melville Jeremy Tscharke Joanna Sumner Mark Antos Peter Johnson	Nick Clemann Peter Robertson Garry Peterson Deon Gilbert Zak Atkins Michael Scroggie
Threatened plants 1 – geophytes, understory species	Marc Freestone (Royal Botanic Gardens)	Marc Freestone Dale Tompkins Susanna Venn Glen Johnson Noushka Reiter Vanessa Craigie Justine Leahy Marie Kealty Nathan Wong David Cameron	Neville Walsh Marc Freestone Noushka Reiter Glen Johnson Jeff Jeanes Andre Messina Arn Tolsma James Shannon James Turner Kerry Seaton Marc Perry

			Pauline Rudolph Susanna Venn Anna Murphy Dan Pendavingh Gail Pollard Wendy Bedggood Abi Smith Ann Lawrie Bill Kosky Chris Jenek Daniel Ohlson David Pitts Donna McMaster Doug Frood John Sillins Karly Learmonth Matt Dell Mike Wicks Neil Anderton Neville Scarlet Paul Foreman Richard Thomson
Threatened plants 2 – shrubs and trees	Dale Tonkinson (CFA)	David Cameron Marc Freestone Dale Tonkinson Nathan Wong Vanessa Craigie Matt White Glen Johnson Neville Walsh Andre Messina	*TBA*