Threatened Species Recovery Hub

National **Environmental Science** Programme

Management of introduced plant species in the Australian Alps: Application of an optimisation framework for allocating resources to address multiple threats

In brief

Alpine ecosystems are subject to a variety of threats, including invasion by introduced plants. For example, alpine peatlands, an Endangered ecological community, are threatened by grey sallow (*Salix cinerea*) and soft rush (*Juncus effusus*) invasions. Limited resources to manage invasive plants means that land managers have to decide where best to allocate those resources. Often multiple actions could be undertaken to reduce impacts from any given threat, and these can vary in feasibility, effectiveness and cost. We developed an optimisation framework to identify the most cost-effective way of allocating resources to address multiple threats when multiple management options are available.

We applied the framework to the management of introduced plant species in two alpine areas. We developed a model of invasion to predict the expected impact in 50 years for each species–action combination that accounted for each species' current invasion state, arrival probability, spread rate and impact, and the management effectiveness of each action.

We found that the recommended action for each introduced plant species changed with budget and there was no single optimal management action for each introduced species. Considering more than one management action could substantially increase the management plan's overall efficiency. Low-effort strategies were rarely included in the optimal solutions, suggesting that concentrating on fewer more damaging introduced plant species with high effort is better than applying less effort to numerous species. Eradication of small infestations was often the most efficient action available and was often optimal when budgets were limited. In contrast, plant containment used on its own was never optimal. Our new decision framework will support systematic planning for the management of multiple threats and aid in the recovery and conservation of alpine ecosystems.

Sphagnum hummocks *(bright green patches in foreground) surrounding a fen on the Bogong High Plains in Victoria. Image: Joslin Moore*

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LEFT: *Lupins invading an alpine peatland. Image: Joslin Moore*

Background

Alpine ecosystems are rare and unique ecosystems in Australia and include the Endangered Alpine Sphagnum Bogs and Associated Fens (alpine peatlands) community, and they provide critical habitat for numerous threatened and endangered species. Alpine ecosystems are subject to a wide variety of threats that vary greatly across the landscape. These include introduced animal and plant species, hydrological disturbance, climate change and increased fire frequency.

Numerous threats and many possible management interventions means that it can be challenging to identify which actions to take first. Limited resources to manage this ecosystem mean that trade-offs must often be made when deciding which threats to manage and where, and gaps in our knowledge make this process even more difficult. Furthermore, threats vary in intensity across space or time and the benefit of addressing emerging threats compared with managing existing threats is often unknown. This makes it difficult to develop recovery plans for the conservation of threatened species and communities including alpine peatlands where each threat can be managed by a range of actions.

Optimisation methods are one approach to improving conservation prioritisation efforts and management performance.

A decision framework can account for multiple threats and incorporate a wide range of candidate management options. The framework identifies which set of threats to target and with which management tool.

Aims

We aimed to devise a decision framework for allocating resources among multiple threats where each threat can be managed by a range of actions. We demonstrated this decision framework using two case studies for the management of introduced plant species which impact the Australian alpine region.

What we did

We devised a framework for allocating resources among multiple threats associated with multiple possible management actions. We applied the decision framework to identify optimal strategies for managing multiple introduced plant species in two areas in the Australian Alps: alpine and sub-alpine areas of the Victorian Bogong High Plains and Kosciuszko National Park's main range alpine area in New South Wales. We aimed to assist managers to improve introduced plant species management cost effectiveness by evaluating trade-offs among different actions with respect to their objectives.

We conducted two three-day workshops with alpine area managers and alpine ecologists to determine the scope of the invasive plant problem in alpine vegetation communities, identify management objectives and actions, and estimate the cost and benefit of different actions. The structured expert elicitation process helped to identify the fundamental objective of all management as *'maintaining and enhancing the ecological integrity, processes and values of the natural alpine environment'*. The group chose a subset of 26 species introduced species that were either present or likely to be introduced to consider at the workshops. The state (whether present and extent of spread) differed between these two locations (see Table 1). Four broad management approaches (prevent, eradication, contain and reduce impact) were identified and their relative cost estimated for two levels of effort. One level of effort reflected current levels, with the second a maximum "no holds barred" level of effort. Eradication only had one level (maximum level) of effort reflecting the fact that once the decision is made all necessary resources are typically applied to eradication. A combination action (reduce and contain) was also included as well as a do-nothing option, resulting a total of 10 possible actions to choose from.

We developed state and transition models to describe the spread of introduced plant species over 50 years, and a scoring system to determine model parameter estimates and calculate the expected benefit of each management action (reduction in area in poor condition). We used the number of hectares of vegetation in poor condition due to the presence of introduced plant species (greater than 5% cover of introduced plant species) as a measure for when management action would be taken. This was because workshop participants considered this level of cover likely to cause negative impacts and trigger a management response. A 50-year period was agreed for evaluation, enabling damage due to future spread to be accounted for.

RIGHT: An alpine peatland around eight years after a fire with an invasive grey sallow seedling (bright green shrub in foreground) emerging from a *Sphagnum* hummock). Image: Joslin Moore

What we did (continued)

We used the optimisation software package IBM ILOG CPLEX Optimizer Studio 12.6.2 to find the optimal solution. We also calculated an approximate solution by ranking the actions by marginal cost-effectiveness. In calculating cost-effectiveness, the benefits of a given action were weighted by management feasibility. We compared the results with three common schemes for allocating resources among invasive species: managing the highest risk species (probability of presence multiplied by the impact if present); prioritising species/actions combinations that resulted in the greatest expected benefit; and choosing the species/action combinations that were the most efficient.

Table 1. *The invasion states and the optimal action at two different budgets for each of the 26 introduced plant species within Bogong High Plains and Kosciuszko Main Range used in our decision framework. Species indicated as NA were not considered for that location. Species are ordered by their degree of spread on the Bogong High Plains and then within Kosciusko Main Range. Each species was classified as being either absent, localised or widespread, where localised indicates that a species is sufficiently restricted that eradication is a possibility. Furthermore, if species were present only in human-modified locations this was indicated with the epithet "modified". Note that all optimal actions represent the highest possible level of effort in all cases except for one species (Sedum acre) on Kosciuszko Main Range which corresponded to low effort. If the optimal action column is blank, it means that the optimal action for that species given the budget, is to do nothing.*

	Bogong High Plains		Kosciuszko Main Range	
Species	Invasion State	Optimal action when Budget = \$2.23 M	Invasion State	Optimal action when Budget = \$2.86 M
Salix nigra	Absent		Absent	Prevent
Senecio madagascari-ensis	Absent		Absent	Prevent
Potentilla recta	Absent		Localised	Reduce + contain
Leucanthemum vulgare	Absent[1]		Widespread	Reduce
Tragopogon dubius	Absent[1]		Widespread	Reduce
Myosotis laxa subsp. caespitosa	Absent		NA	NA
Barbary verna	NA	NA	Localised modified	
Dactylis glomeratus	Localised modified		Localised modified	
Sedum acre	Localised modified		Localised	Reduce
Phleum pratense	Localised modified		Widespread modified	
Holcus lanatus	Localised modified		Widespread	Reduce
Fallopia japonica	Localised modified		NA	NA
Viola arvensis	Localised modified		NA	NA
Pilosella officinarum subsp. *officinarum*	Localised	Reduce + contain	Absent	Prevent
Pilosella piloselloides subsp. *bauhinii*	Localised	Reduce + contain	Absent	Prevent
Pilosella aurantiaca subsp. *aurantiaca*	Localised	Reduce + contain	Localised	Reduce + contain
Achillea millefolium	Localised		Widespread	
Anthoxanthum odoratum	Localised	Reduce + contain	Widespread	Reduce
Cytisus scoparius	Localised	Reduce + contain	Widespread	Reduce
H. perforatum subsp. *veronense*	Localised		Widespread	Reduce
Juncus articulatus	Localised		NA	NA
Erythranthe moschata	Localised		NA	NA
Lotus uliginosus	Widespread modified, localised natural		Absent	Prevent
Juncus effusus	Widespread	Reduce	Widespread	Reduce
Hypochaeris radicata	Widespread		NA	NA
Salix cinerea	Widespread	Reduce	NA	NA

[1] *These species were not present on the Bogong High Plains when the workshops were held but have since been reported on the Bogong High Plains (as of 2021).*

Key findings

When resources were unlimited, the decision framework identified that the maximum possible reduction in impacts from invasive plants from management actions at the Bogong High Plains was 46%, and for Kosciuszko National Park 52%. In both cases, most of this benefit to the ecosystem could be achieved well before the entire budget was spent. The analysis predicted that 98% of the manageable impact could be avoided by managing seven introduced plant species in Bogong High Plains with an annual budget of $2.2 million; and 99% of manageable impact could be avoided by managing 15 introduced plant species in Kosciuszko National Park with an annual budget of $2.85 million. The reduction of ecosystem impact due to management declined nonlinearly as the management budget increased, as shown in Figure 1.

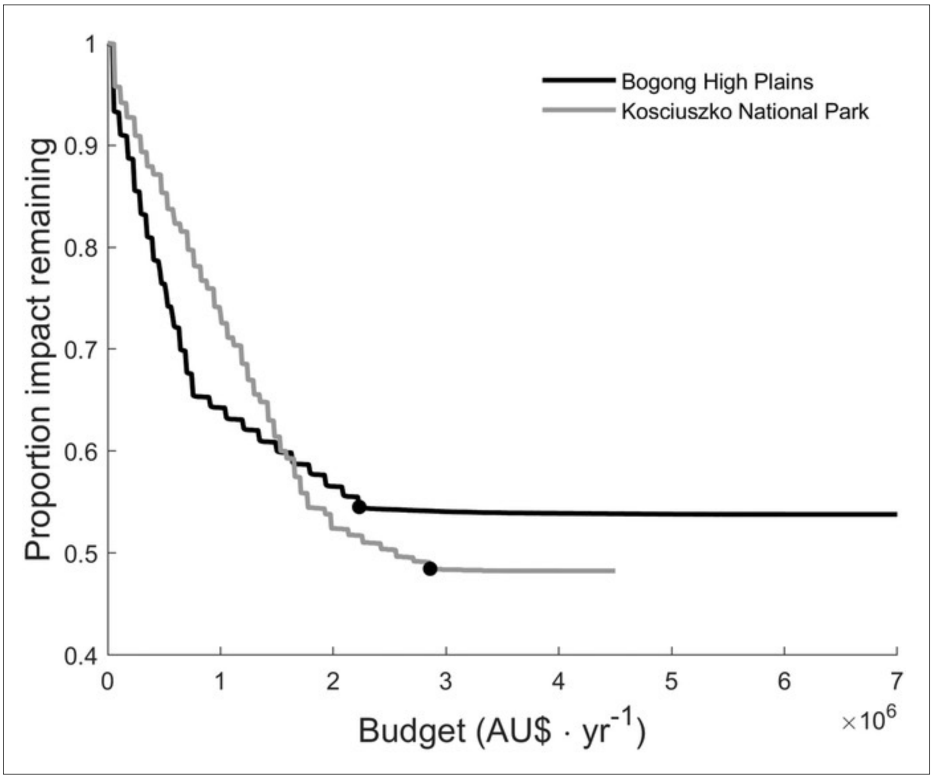

Figure 1. Cost-effectiveness curves for the management of multiple introduced plant species for the Bogong High Plains and Kosciuszko National Park. Filled circles indicate the budget required to manage 98% and 99% of the manageable impact for the Bogong High Plains ($2.23 million) and Kosciuszko National Park (AU$2.86 million), respectively. Effectiveness is expressed as the proportion of impact remaining from introduced plants after management compared with doing nothing. Image Moore et al (2021).

As the budget changed, the model identified different introduced plant species to target and different management actions. The optimal action and effort applied to some introduced plant species fluctuated depending on budget whereas, for other introduced species, actions were more consistently included or excluded from the strategy. Kosciuszko had more widespread and less localised invasive plant species than the Bogong High Plains, resulting in different sets of priority species and actions for the two areas. For example, a prevention strategy is recommended for lower budgets

An alpine peatland around seven years post-fire with invasive grey sallow seedlings (bright green shrubs). The grey tree branches are snow gums that were burnt in the fire and are re-sprouting from the base. Image: Joslin Moore.

Key findings (continued)

in Kosciusko National Park than in the Bogong High Plains.

An invasive plant containment strategy used on its own was never optimal, reflecting park managers' perception that weed containment is both expensive over the longer-term and likely to fail.

The eradication of invasive plants was often the most efficient action identified because although eradication is expensive, we assumed it occurred over a finite period (20 years) and therefore, it would have a lower total cost than actions undertaken indefinitely (50 years). Hence, eradication was often optimal when budgets were restricted. As the available budget increased, impact reduction strategies typically replaced eradication. This reflected the land managers' perception that successful weed eradication is hard to achieve. Although expensive, impact reduction was considered a more reliable management strategy because on average it provides a better outcome for the alpine ecosystem.

The framework identified contrasting management priorities between the Bogong High Plains and Kosciusko National Park. This indicates that the management of a specific threat depends on what other threats are present and what resources are available. Given a similar budget, the optimal strategy for the Bogong High Plains was different to that for Kosciusko National Park. For the Bogong High Plains, when the budget is $2.23 million (marked location on Figure 1). The optimal strategy was to use the reduce impact (high effort) action on two out of the three widespread weed species and reduce and contain five of the eight localised weed species in natural habitats (high effort) action (see Table 1 for which species).

Our resource allocation framework identifies which action to apply to each of introduced plant species. This new approach enabled us to consider multiple levels of effort as well as contrasting actions (e.g., containment vs eradication). Considering multiple effort levels incorporates the trade-off between resource use and management effectiveness into the prioritisation framework. Incorporating this trade-off means it is possible to assess the relative merits of managing many threats with low effort or concentrating on fewer more damaging threats with high effort. Low-effort strategies were rarely included in the optimal solutions, suggesting that it is often better to concentrate effort on fewer more damaging threats rather than to put in less effort to numerous threats.

The performance of the model was most sensitive to estimates of the introduced plant species' impacts and management feasibility (how likely it was that the management actions would be successful), with much lower sensitivity observed for the probability of arrival and spread rate. This highlights how important it is to better monitor and measure both the ecosystem impacts caused by introduced species as well as the success or otherwise of management actions.

Alpine peatland dominated by candle heath (Richea continentis) *with a small pool in the foreground. Image: Joslin Moore*

LEFT: *Alpine feldmark near Mt Kosciuzko with the mauve flowers of feldmark eyebright (*Euphrasia collina subspecies lapidosa*). Image: Joslin Moore.*

Recommendations and implications

The framework can be used to support land managers to identify an appropriate management strategy given available resources that will maximise ecosystem condition and the available habitat for threatened species and provide the best return on investment. The case study developed considered alpine and sub-alpine ecosystems more broadly than just peatlands. However, a number of important weeds of peatlands (Grey Sallow, Soft Rush) were included in the study and were high priorities for control.

With further work, the framework could be applied to the management of both introduced plants and animals specific to alpine peatlands rather than alpine areas more broadly. As well as guiding management priorities, the decision framework would also allow managers to quantify the expected changes in alpine peatland condition over time and combined with monitoring, would enable managers to objectively evaluate the results of management actions. Improving the management of peatlands is expected to have flow-on benefits for numerous threatened and endemic species that inhabit these areas.

We found that choosing one from a suite of actions for each threat and not anchoring a single management action for all budgets could increase the effectiveness of management plans developed from this framework. Our framework extends cost-effectiveness analysis to allow consideration of multiple threats with multiple candidate actions for each threat.

*Snow daisies (*Brachyscome nivalis*) in flower looking back towards the main range at Kosciuszko National Park. Image: Joslin Moore*

Further Information

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Citation

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