MANAGING FOR ECOSYSTEM CHANGE IN THE GREATER BLUE MOUNTAINS WORLD HERITAGE AREA

Executive Summary

Australian Research Council Linkage Project LP0774833

Project partners:

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A. Project overview and objectives

Introduction

Australia's nature reserve system is an important means of protecting biodiversity. One of the most outstanding reserve systems is the Greater Blue Mountains, declared a World Heritage Area (WHA) in the year 2000. It is the largest continuously forested area in NSW and provides an important refuge for biodiversity, hence its listing as World Heritage.

However, reserve protection alone is not sufficient to guarantee biodiversity conservation. Ecosystems and the threats to their integrity need to be actively managed, and like all natural areas, the Greater Blue Mountains World Heritage Area (GBMWHA) will have to adapt to the added stresses brought on by climate change. 'Drivers of change' such as climate change, introduced species, and fire, are significant factors involved in management of the WHA.

The three-year ARC Linkage project titled 'Managing Ecosystem Change' was initiated by the Blue Mountains World Heritage Institute (BMWHI) to assess drivers of change and to model projections of possible ecosystem change that may inform management planning. The project created building blocks that are valuable for the future integration of science into decision-making for the WHA within an adaptive environmental management framework. This Executive Summary highlights research outcomes and addresses challenges and future opportunities arising from this ambitious multi-disciplinary project.

Project overview

The core of this project was the development of computer models that could project future ecosystem changes. Large-scale spatial models were built for examining the distribution of biodiversity across the World Heritage Area, based on the use of surrogate species and ecosystems, along with the spatial impacts of drivers of change. This involved collating all available ecosystem data for the region and compiling it into a geographic information system (GIS) database. The project engaged scientists across a range of disciplines, including nine Chief Investigators, two Research Fellows and three Research Assistants. A total of nine postgraduate projects were undertaken within the overall project (five PhD, two Masters and two Honours). Various project components provided knowledge relevant to reserve design, ecological representation, invasive weeds, threatened communities, ecosystem modelling, and adaptive management.

Change was modelled for a total of 700 species. This is an important outcome, especially given that the eucalypts in the Myrtaceae were a key reason for listing of the World Heritage Area. Another major outcome for this project was the development of a tool that modelled the likely extent of upland swamps under IPCC climate change scenarios.

Student research was primarily based on collating fine-scale information on responses of biodiversity surrogates to drivers of change (e.g. fire, climate change, and invasive species). Projects were also established to develop new modelling approaches, as most available approaches were not suitable to handle the very large datasets. A large computer array and associated software was built to enable the data to be modelled. Computer models were built using representative ‘surrogates’ of species. As important surrogates for overall biodiversity, the following four key surrogate groups were focused on:

1. All species in the plant family Myrtaceae including *Eucalyptus* species, the diversity of which (over 100 species) was one reason for World Heritage listing.
2. All species in the plant family Fabaceae. The Fabaceae are a diverse family involved in nitrogen cycling in the WHA.
3. All terrestrial mammal species (excluding bats). Mammal diversity is also a key aspect of biodiversity, with many threatened species in the WHA.
4. Upland swamps are an endangered ecological community under the Commonwealth EPBC Act and also vulnerable under the NSW Threatened Species Conservation Act.

Distribution models of environmental niches were developed for all four surrogate groups across the World Heritage Area and surrounding areas. Maps of diversity and representation were created, as were tools to assess how these surrogates were affected by drivers of change. Predicted changes in environmental niches were examined for a range of IPCC climate scenarios and increases in fire frequency and area.

Project objectives

The overall aim of this project was to inform management of the Greater Blue Mountains World Heritage Area by building the knowledge base about key drivers of ecosystem change (climate change, fire and pests), and to assess their impacts on biodiversity. Specific objectives were addressed in five main areas:

1. **Past and current ecosystem condition**
   - Construct a GIS database and collate all available biodiversity information for the World Heritage Area
   - Develop Myrtaceae and Fabaceae habitat suitability models, including hotspots and climate impacts
   - Develop fauna habitat suitability models, including assemblages and climate impacts
2. **Reserve effectiveness**
   - Quantify the distribution of surrogate species and assess representation and efficiency of surrogates
   - Incorporate economics into surrogate modelling
   - Explore the effectiveness of the current reserve boundary, by comparing a historical perspective on the establishment of the reserve with the current status of biodiversity within the GBMWHA
   - Calculate complementarity to identify conservation planning units and effectiveness
3. **Responses to drivers of change – impact and spatial extent**
   - Map the spatial extent of drivers of change
   - Assess dispersal ability of plant species in response to climate change
   - Measure resource overlap and interactions between native and introduced apex predators
   - Model habitat suitability for lantana as an example of invasive weeds
   - Assess resilience of upland swamps to climate change
   - Assess surrogate species responses to climate change and fire regimes
4. **Modelling ecosystem condition and drivers of change**
   - Model threat distributions and their impacts on chosen surrogates
5. **Adaptive management**
   - Inform a monitoring strategy for the GBMWHA within an adaptive management framework

B. Key findings and management implications

1. Past and current ecosystem condition

What was learnt about the current condition of ecosystems within the GBMWHA?

- The construction of a GIS database using all available data for ecosystems in the WHA formed the basis for building understanding of ecosystem condition. This database provides an important foundation for management and future research that addresses specific biodiversity management problems.
- A series of habitat suitability models were constructed focusing on a range of priority species including all species in the plant families Myrtaceae and Fabaceae, and all mammals (excluding bats). Maps of their distributions were produced. Environmental niche models of the surrogate upland swamps were created to assess their resilience to ecosystem change.

How accessible will the GIS database be to management agencies?

- The database is held at the University of NSW (UNSW) and is accessible online for authorised users for some tools, such as the upland swamp modelling tool. A website was developed to both provide access to the data and to provide an understanding of what it contains (www.wetrivers.unsw.edu.au/Blue_Mountains_Project/BM_home.html).
- Access past the life of the project needs to be further developed so that the capacity may be better utilised by managers. Follow-up projects will be needed to maximise deliverables and improve access.

2. Reserve effectiveness

How has the reserve changed over time in terms of its configuration?

- Two approaches were taken to answer these questions, both utilising surrogate groups of species. Two key biodiverse plant families were used - Myrtaceae and Fabaceae. Along with these, mammals were modelled as a key subset of animal diversity.
- Using the plant family Myrtaceae, diversity and endemism with respect to the WHA were examined. It was found that 20% of Myrtaceae are range-restricted to the reserve which, on average represents 20% of the range of a species that occurs within it.
- Marxan software was used as an aid for modelling reserve design, to examine the efficacy of the WHA to encompass Myrtaceae representation over time. It was found that systematically-selected increases in reserve area improved representation of Myrtaceae over ad hoc historical increases. Representation of rare species was also increased, suggesting that systematic approaches have utility for conservation planning in the WHA.
- Spatially-explicit information was created on the distribution, abundance, and hotspots of native terrestrial mammals in the WHA and in NSW.

Does the reserve capture key areas that are important for biodiversity representation?

- The relationship between reserve size and biodiversity (in this case for the plant family Myrtaceae) was examined. Land parcels important to maintaining endemism were identified both within and outside the WHA boundary (within 100 km). Mapping showed that while the WHA had captured significant areas of Myrtaceae biodiversity, there were areas (especially to the west of Kanangra Boyd) that would improve the representation of this surrogate.
- A template was provided for quantifying representation of biodiversity hotspots which lends support to systematic reserve design approaches using complementarity to select parcels of land for acquisition.
- A new approach was developed for incorporating spatial proximity as a cost-function in Marxan analysis, enabling potential new areas to be assessed. This provides an alternative solution for use by reserve planners when extending reserve systems.
- Significant capacity was built that can inform future work addressing likely edge effects and the long-term viability of the reserve in protecting biodiversity.

How well can we predict mammal distributions?

- The ATLAS dataset was used to produce large-scale predictions of mammal distributions. These predictions can be used to provide management with spatially explicit recommendations for maximizing and optimizing conservation objectives.
- Predictions were brought together to help identify areas of high taxonomic and functional diversity.
- The importance of genetics and functional characteristics were evaluated as possible means of identifying possible surrogates (i.e. level of spatial overlap).

3. RESPONSES TO DRIVERS OF CHANGE (THREATS)

What monitoring is necessary to track changes in biodiversity?

- The efficacy of sampling methods for establishing robust habitat suitability maps for all mammal species across NSW was examined. It was found that, for the purposes of creating robust maps, opportunistic sightings were more cost-effective and satisfactory for most species. This finding related to identifying the best way to predict suitable habitat for species. It does not imply that other sampling methods are not needed to obtain information on other important ecological parameters (e.g. behaviour, demographics, ecological interactions).

What is the potential spatial impact of climate change and fire on biodiversity surrogates?

- Potential impacts of climate change and fire were assessed using all plant species in the Myrtaceae and Fabaceae, all mammal species, and upland swamps.
- Simulations were created highlighting potential impacts on diversity and community resilience. Under different scenarios, land parcels under threat were identified, suggesting ways to allocate funding on the basis of this knowledge.
- Some upland swamps were shown to be at serious risk as climate changes.

How do weed distributions alter with environmental change?

- Using lantana as a surrogate weed, its distribution was modelled within the Blue Mountains City Council area and its relationship to environmental, climate and management factors was examined.
- One key invasive plant species was modelled, but further research to address this question can utilise the capacity developed to model other invasive weeds in the WHA.
- Temperature was found to be the most important factor limiting lantana's presence to the lower mountains. 15% of the Blue Mountains City Council Local Government Area is considered suitable for lantana at present, but increases to 58% after a simulated 3°C rise in temperature.
- At least 20% of the area of five endangered ecological communities is considered suitable for lantana (containing at least 27 threatened species).
- The research places additional urgency on the need to contain weeds such as lantana now, as they will only become more problematic with increased temperature and disturbance.
- The research identifies pathways of spread for lantana into the GBMWHA
- Use of strategic monitoring and assessment for lantana can cut management costs dramatically by targeting smaller fringe patches before they become large infestations.

What strategies are plants currently using to disperse in the Greater Sydney Region?

- Approximately 63% of species in the Greater Sydney Region have no dispersal information. Models to predict the dispersal mechanisms of species were created to predict the correct dispersal mechanism for species. Ant dispersal is extremely common
- Estimates were developed for potential dispersal distances of species in the WHA.
- Ant dispersal at different elevations was examined to understand how this dispersal system works (using *Acacia terminalis*). There is significant difference in the seed removal agents at low elevation compared to high elevation sites.
- Vegetation surveys will be conducted at hanging swamps to identify the role spatial isolation plays on the composition of plant communities. This work aims to see how the species composition of hanging swamps alters as swamps are more spatially isolated in the landscape.
- A large database of plant species dispersal mechanisms in the WHA has now been collected, and will be available for managers. This work has highlighted the need for

basic plant trait information to be collected. The developed models can be used to gain estimates of the dispersal mechanisms of species and give estimates of the potential dispersal distances that species can reach.

How do exotic and native apex predators in the GBMWHA interact?

- The research investigated diet, activity and distributions of apex predators. Target species included dingoes/wild dogs, foxes, feral cats as well as vulnerable native species such as the spotted-tailed quoll and powerful owl and lace monitor.
- Results suggest that dingo/wild dog populations may play a vital role in limiting fox numbers. Diet data also implicates predation and competition by the fox as being more likely than the dingo/wild dog to threaten native predators and prey.
- The fox also has high levels of diet overlap with the spotted-tailed quoll, which has already undergone significant range restrictions, and this may pose a threat to ongoing viability of this endangered species. Where the distribution of foxes and spotted-tailed quolls overlap, competition for prey species is more likely to occur than between foxes and powerful owls, which are a more specialised predator.
- A management concern is that ongoing lethal control of dingoes/wild dogs at the edges of the GBMWHA may lead to population increases of exotic mesopredators (e.g. foxes, cats) which impact on native predator and prey species. Control methods which target foxes (mostly the laying of 1080 baits), also kill wild dogs, further altering the dynamics of apex predators. Again the result may be release of mesopredators such as the feral cat, which would alter the predation dynamics and competition pressures.

4. MODELLING ECOSYSTEM CONDITION & DRIVERS OF CHANGE

Can bioindicators be used to assess impacts of threatening processes on biodiversity, and how resilient is biodiversity within WHA reserves and beyond to drivers of change (present and future)?

- The project focused on surrogates of flora (Myrtaceae, Fabaceae), fauna (mammals), and ecosystems (upland swamps) to assess their potential response to changes in climate and fire regimes under various IPCC scenarios. This covered 700 species. The project modelled projections for these over time with climate change and identified which swamps would be at risk in a warming world.
- Maps of diversity were created for the Myrtaceae and Fabaceae plant families. To evaluate how diversity in these might change, IPCC climate scenarios were simulated, with changes to fire frequency (and areas) across the landscape. Changes were predicted in environmental niches of all species, and diversity recalculated. Poor environmental conditions for diversity were observed to increase along valley floors, particularly in the upper Hunter under climate change.
- The ability of family relationships in mammals to assist with prediction of suitable environmental habitat was examined, enabling predictions to be made for species with few sightings.

- Methods were developed to examine potential change in vegetation communities due to climate change, and how this approach could be used by management to target areas of potential concern.
- Managers may be able to allocate spending to mitigate or ameliorate impacts to biodiversity hotspots.
- Understanding trends and interpreting forecasts in the context of species, populations, communities and ecosystem processes (and their management) are important for effective biodiversity conservation in the WHA.

5. Adaptive management

How adaptive is management of the GBMWHA?

- While the objective to develop an adaptive management framework was not able to be progressed by the project, significant capacity has been built that will provide a foundation for an adaptive management approach.
- Multiple government agencies are involved in management of the GBMWHA, and decision-making is complicated by numerous plans of management and competing values and goals, An adaptive learning-by-doing framework is needed to provide transparent linkage between science, management and policy.
- A lack of monitoring to document the biodiversity outcomes of management actions is a major impediment to adaptive management in the GBMWHA.
- Another key impediment to adaptive management is the lack of clearly defined management objectives – existing broad management questions are insufficient. Development of an adaptive management framework with clearly defined management objectives can provide for integration of new knowledge and new decision-making mechanisms for fire and pest species. A framework is needed that links high-level goals across management (e.g. fire and pests, along with socio-political goals) with on-ground monitoring that informs management actions.

C. Project feedback

The final workshop to report back on the project was held on March 11th 2010 at UNSW. The partners were keen to explore how to improve future collaborative research projects in the future, and small group discussion focussed on the questions of what worked, what didn't and where to next. The combined results from the groups are shown below.

What worked:

Research output

- A complex issue was addressed using a holistic approach.
- A multidisciplinary team of researchers generated new research ideas.

- Worthwhile results were produced e.g. seed dispersal, dingoes, and predictive outcomes for climate change.
- The project came to grips with important drivers of change and utilised 'shelved' data that was not being used.
- Capacity for day-to-day management (e.g. with database) can help with short-term effects on ecosystems (e.g. fire).
- Benefits were produced for students through working on a large integrated and well-funded program and utilising the capacity of a large database.
- Longer-term spin-offs such as a PhD on adaptive management.
- Human capital was developed, in particular through student training, generating long-term human capital benefits.

Database utility

- Knowledge for the WHA was condensed into a single database.
- Computational capacity was developed e.g. a large GIS database that didn't previously exist. The modelling tools are a legacy for WHA management.

Communication and collaboration

- The project presented networking opportunities between researchers and managers and between agencies.
- Ongoing partnerships were created.
- There was some 'adaptiveness' in the group, in that there was learning over time.

WHAT DIDN'T WORK:

Research output

- Putting a value on knowledge, in terms of what is useful for managers vs. what may be useful for an academic research project. In a project like this, knowledge is valued differently by the different participants.
- ARC funding is driven toward *academic* outputs (not management).
- Difficult for researchers to match research objectives to management when managers were unable to define the management objectives.

- This was a ‘blue sky’ project, which meant there was a need for modified expectations. Prioritisation of the objectives with partners at the start of the project may have helped to better match expectations with delivery (e.g. in terms of adaptive management). High expectations at the start were not modified when the initial funding target was reduced. Objectives should have been modified. Due to the funding reduction, the adaptive management component was dropped off, but this was not made clear to the partners. However the new PhD that was instigated toward the end of the project will hopefully address this

Database utility

- How do we transfer the capacity to managers? The pathway is as yet unresolved. At the completion of three years of funding, no tool is yet available that can be used by the agencies (although agencies did get a concept for the tool). The technical skill level required to use the database means it will probably be a specialist tool. The question of how to cope with possible departure of key staff who are familiar with the database and its use was raised.
- There is a need for more clarity as to what managers *expect* from the database – this issue is unresolved.
- It is not resolved what *format* managers require for the project database to be in.

Communication and collaboration

- Researchers are dispersed and multi-disciplinary and agencies are dispersed, hence it is hard to be cohesive.
- The ‘disconnect’ between researchers and managers remained throughout the project.
- Inconsistent input from project partners.
- No grant money was allocated for BMWHI to invest time on communication and partner liaison or adaptive management (although this was seen as their role).
- Communication between agencies – while staff members were willing to share information, they were inhibited by organisational protocols and possibly territorial and political barriers.
- Communication complexity *within* organisations was a problem (e.g. stratified and longitudinal).
- Key individuals needed to be identified across agencies to make communication work.

- More (and earlier) communication was needed between researchers and managers regarding on-ground management.

- More regular and earlier forums would have been good, e.g. in the local regions with the area managers and rangers.

Public engagement

- Engagement at the public/community interface was largely absent (there were no resources for this).

WHERE TO NEXT:

Database utility

- Resolve issues with the database so it is a deliverable tool, including addressing issues of *access* i.e. who and how (e.g. training), and whether the agency has the necessary hardware.

- Follow up with DECCW modelling section at Wagga Wagga to integrate the capacity developed through this project.

- Possibility for UNSW to train DECCW staff on the modelling capacity developed.

- Application of capacity that was developed to more fire projects (integrate with Prof. Ross Bradstock's work at Wollongong University).

Future research output

- Development of an adaptive management framework including identifying 'thresholds of potential concern' for the WHA. The next steps in this process could be:

    - Clarifying management objectives within a hierarchy of objectives that maps out and integrates the range of objectives for the World Heritage Area.
    - Designing a monitoring program in line with these objectives, including defining 'thresholds of potential concern' for a range of ecological variables.

- Identify other risks for WHA using the modelling capacity.

- Universities should formally enrol staff from partners as *co-supervisors* for students in future WHA research.

- State-wide assessment of fauna developed through a PhD may be useful for DECCW biodiversity strategy.

- 'Decision support tools' could be developed for DECCW.
- DECCW needs to resolve 'making space' for similar research projects within a big corporate agenda.
- Assess whether the UNSW Water Information System for the Environment (WISE) is useful to collate information about the WHA.
- Potential future Hons projects based on pest monitoring in and beside the WHA with DPI.

Communication and collaboration at the research/management interface

- Develop website/blog/online forum – for scientists, students, managers, field staff, modellers – a two-way feedback system.
- 'Travelling road show' of students/ researchers to regional offices should be held soon for students to present their research to managers and field staff.
- In addition to writing a thesis and publications, students should write a report for managers (material outputs that are usable and absorbable by managers).
- Students could give talks to DECCW science seminars.
- Explore opportunities for future employment/ engagement of students with managers.
- Ongoing engagement of researchers and BMWHI with DECCW 'Management Effectiveness Unit'.
- BMWHI to be central liaison/ facilitating node for ongoing engagement and research with the network built up through this project.

Public engagement

- Engagement at the public/community interface – effort is needed to communicate the outcomes and implications of the completed and ongoing research (BMWHI to seek funding).
- Development of community awareness tools e.g. hanging swamps and climate change.

D. CONCLUDING COMMENTS

The ‘Managing Ecosystem Change’ project represents **the first major integrated research effort for the GBMWHA**, with several projects brought together under a single umbrella. Previously, the research effort has generally been disparate and focused within disciplines, and not integrated across projects or ecosystems or their components. Addressing this need is a major mission of the Blue Mountains World Heritage Institute (BMWHI). It has been stimulating to witness the development at UNSW of a large research team focussed on the World Heritage Area. It is important that this capacity and momentum is maintained – for the mutual benefit of the agencies, the researchers and the World Heritage Area. This project will hopefully serve as a launch pad for ongoing useful research focusing on the Greater Blue Mountains region.

The project has highlighted the **complexities and challenges of marrying research with management**. While scientific research is valuable in its own right in terms of creation of new knowledge, for the World Heritage Area, such research is most important in terms of how it informs management.

The project has also highlighted the importance of an **adaptive management** framework for utilising research outcomes. Without such a framework, integrating research into management is difficult and uncertain, as this project has demonstrated. This project has built significant capacity to model how drivers of change may impact the WHA in the future. BMWHI recognises that **access to the database capacity** developed in this project remains an unresolved issue. As a ‘knowledge broker’, BMWHI is keen to assist in resolving this to ensure the maximum delivery of outcomes to land managers. Some of the modelling tools developed through this research program are accessible by research partners online. However, the full modelling capacity requires a powerful computer array, which most agencies (to date) do not have. Consequently, much of the modelling capacity developed is currently usable only at UNSW. In terms of ongoing research, this capacity is already being built upon through a number of new projects, including a PhD focusing on integration of research into management using this project as a case study, a PhD modelling *Phytophthora* spread in the WHA in response to climate change, and an ARC project involving Sydney Catchment Authority and NSW DECCW.

Looking to the future, the best outcome would be that this project - with its capacity to model future ecosystem changes - should continue to assist land managers in the adaptive management of this outstanding World Heritage Area.