Bushland and Urban Biodiversity Management in a Changing Climate

Part 5 – Case Study

Investigation of Potential Effects of Projected Climate Change on EVCs and Selected Key Species in the EAGA Region of eastern suburban Melbourne.

This case study forms part of the project
"Bushland management and climate change:
Adapting management practices in response to landscape change"
as developed by the Eastern Alliance for Greenhouse Action.

This project is funded through the Victorian Government's
Sustainability Fund under the Victorian Local Sustainability Accord.

Updated May 2013

EAGA
EASTERN ALLIANCE FOR GREENHOUSE ACTION

Victorian Local Sustainability Accord

Sustainability Fund Managed by Sustainability Victoria

Victoria The Place To Be

The Eastern Alliance for Greenhouse Action (EAGA) comprises Booroondara City Council, Knox City Council, Monash City Council, Maroondah City Council, Whitehorse City Council and the Yarra Ranges Shire Council.

This project is funded through the Victorian Government's Sustainability Fund under the Victorian Local Sustainability Accord.

Prepared by:
Steve Meacher,
Eastern Alliance for Greenhouse Action (EAGA), Shire of Yarra Ranges

Enquiries should be addressed to:
Steve Meacher
Eastern Alliance for Greenhouse Action
Environment Department
Yarra Ranges Council
PO Box Lilydale, Vic 3140

Executive Summary and key findings

This case study was selected from several proposals submitted at a workshop held in Ringwood (July 2010) as part of an investigation of the potential impacts of climate change on bushland and biodiversity under the councils' management and how management practices might need to be changed in response.

Previous studies (Hughes, et al., 1996; Nitschke and Hickey, 2007) have identified a narrow climatic breadth of many Australian species. CSIRO projections indicate that the "most likely climate future" for the region in 2050 and 2070 (under a 'High emissions' scenario) would be significantly hotter and drier. Such climatic changes will have strong impacts on natural environments, some of which have already been observed.

This study seeks to investigate a method of generating local information that will be of practical value to "on ground" bushland and biodiversity managers.

The native vegetation within the area covered by the six LGAs was quantified and lists of species for each EVC were compiled. Species that were considered ecologically important or characteristic /diagnostic for the integrity of the subject EVC were selected for bioclimatic modelling.

The modelling produced maps which revealed projected changes in the zones of climatic suitability for each species at three time steps, 2020, 2050 and 2080. The maps were studied and the observed changes were recorded and analysed.

Key findings

- All species may be affected in some parts of their ranges.
- General trend in the EAGA region is for species distribution to shift toward the North-East.
- Most change is often observed at extremes of distribution, outside EAGA region.
- Strong change indicated for *Eucalyptus ovata* and *Eucalyptus rubida.*
- Few species show no change in the EAGA region, some show little change.
- Species in an EVC appear to respond independently of each other, not together.
- EVCs may be ranked according to vulnerability to climate change.
- Bioclimatic modelling could be valuable in projecting the potential effects of climate change on species and EVCs. This may assist councils in allocation of resources to manage and preserve bushland and biodiversity values.
- Monitoring for indications that species' distributions and EVC compositions are changing will be needed.

Introduction

This case study was selected by the project steering committee from several proposals submitted at a workshop held in Ringwood (July 2010). The workshop was hosted by the Eastern Alliance for Greenhouse Action (representing the councils of Boroondara, Knox, Maroondah, Monash, Whitehorse and Yarra Ranges), as part of an investigation of the potential impacts of climate change on bushland and biodiversity under the councils' management and how management practices might need to be changed in response.

At the workshop representatives of the six Local Government Authorities (LGAs) and community members were presented with, and responded to, information on climate change science, projected climatic changes in the region and observed and potential environmental effects. Participants were asked to identify issues for biodiversity management and to make suggestions for a "case study" which would investigate techniques and/or provide information to assist management decisions.

Among the literature provided at the workshop was a study (*Climatic Range Sizes of Eucalyptus Species in Relation to Future Climate Change*, Hughes, Cawsey and Westoby 1996), which investigated the climatic envelopes (the ranges of temperature and precipitation) within which 819 species of *Eucalyptus* currently occur. The study found that 25% of eucalypts have a range of mean annual temperature of less than 1°C; 41% have a range less than 2°C; 53% have range less than 3°C and 73% less than 5°C. The study also found that 23% of eucalypts have a range of less than 20% change in mean annual precipitation and 35% have a range of less than 40%. The narrow climatic breadth of Australian species identified in this study was also observed by Nitschke and Hickey, 2007.

It is known that the Earth's climate is changing as a result of a combination of human activities, including the burning of fossil fuels and land-clearing. The global average temperature has already risen 0.8°C above the pre-industrial level and greater changes are expected in the future. Such changes are not evenly distributed but vary according to location.

To provide a better understanding of potential climate change in the region, EAGA had commissioned a study from CSIRO, *Climate Futures for Eastern Melbourne* (July 2010). The projections were presented at the workshop and indicated that the "most likely climate future" for 2050 (under a 'High emissions' scenario) would be up to 2.2°C hotter and drier, with up to 13% less rainfall. By 2070 the "most likely climate future" was up to 3.0°C hotter and much drier, with up to 21% less rainfall.

Such climatic changes will have strong impacts on natural environments, which have evolved within limits of natural variability. Globally and regionally a range of changes has already been observed and recorded and further changes are expected.

One of the "Knowledge gaps" to emerge during following discussions was the lack of information about the nature and extent of climate change impacts on biodiversity at a local level. The selected proposal seeks to investigate a method of generating local information that will be of practical value to "on ground" bushland and biodiversity managers. The concept was to identify the Ecological Vegetation Classes (EVCs) in the region and select particular 'indicator' or 'diagnostic' species. Modelling similar to that conducted by Hughes *et al*. would then be conducted to determine the potential effects of projected climate change in the region. Such modelling might then suggest and inform management strategies and responses. This will assist local government authorities (LGAs) as the primary agencies responsible in Eastern Melbourne for the management of biodiversity and natural resources on public and private land in urban, suburban and peri-urban areas.

Data & Methods

The research for this study was conducted in several stages, each stage involving different contributors; identification of EVCs in the region, listing of species present in those EVCs, selection of species for modelling, bioclimatic modelling and interpretation. Full details of the parts of the study are available in the appendices.

<u>Native vegetation and Flora lists within the EAGA region (ARCUE)</u>

The native vegetation within the area covered by the six LGAs (with the exception of part of Yarra Ranges outside the Urban Growth Boundary) was quantified using the EVC data layers for 1750 and 2005, obtained from the DSE Spatialsmart dataset. The Clip function within ArcGis 9.3 was used to select areas of each EVC within each LGA. Hawth's Tools extension (v 3.27) was used to calculate the area of each EVC. Lists of species for each EVC were obtained from the Victorian Department of Sustainability and Environment's website and complemented with data records from the Flora Information System (FIS).

<u>Selection of key species (Graeme Lorimer, Nicholas Scott Williams and Darren Wallace)</u>

Three botanists with expertise in the plant communities in the region were asked to examine the lists and identify species that were ecologically important or characteristic /diagnostic for the integrity of the subject EVC. The three sets of responses were collated and the following list of 21 species was submitted for modelling.

Eucalyptus camaldulensis	River Red Gum	*Acacia dealbata*	Silver Wattle
E. cypellocarpa	Mountain Grey Gum	*A. melanoxylon*	Blackwood
E. obliqua	Messmate	*Coprosma quadrifida*	Prickly Currant
E. macrorhyncha	Red Stringybark	*Melaleuca ericifolia*	Swamp Paperbark
E. viminalis	Manna Gun	*Spyridium parvifolium*	Dusty Miller
E. ovata	Swamp Gum	*Exocarpos cupressifomis*	Cherry Ballart
E. melliodora	Yellow Box	*Olearea argophylla*	Musk Daisy-bush
E. cephalocarpa	Mealy Stringybark	*Dicksonia antarctica*	Soft Tree-fern
E. regnans	Mountain Ash	*Tetrarrhena juncea*	Forest Wire-grass
E. rubida	Candelbark	*Themeda triandra*	Kangaroo Grass

Phragmites australis Common Reed

Bioclimatic modelling (Rachael Gallagher, Macquarie University)

The distribution maps in Appendix 2 were produced using Maxent (version 3.3.1). Projected distributions for the 21 selected species were based on current distribution records accessed through Australia's Virtual Herbarium (AVH) in March, 2011. AVH Records for each species were used to build species distribution models (SDM's) in Maxent, based on average baseline climatic conditions between the years 1950-2000. The baseline climate data was accessed through the Worldclim web application.

All species distribution models (SDMs) were created at a 5 arc minute grid resolution across Australia, approximately equivalent to 8km x 8km. SDM outputs for baseline climate conditions were projected onto future climate surfaces for the decades centered around 2020, 2050 and 2080. These were derived from four atmosphere-ocean general circulation models (GCMs) run under an A2 emission scenario, considered the most likely future scenario under current global emissions trajectories. The four GCMs used in this study (BCCR-BCM v.2, CSIRO Mk 3.5, INMCM 3.0 and K-1 Coupled GCM (Miroc) v. 3.2.2 medium resolution) were chosen because evaluations indicate they perform well at modeling Australian climate conditions.

Results

The maps produced through bioclimatic modelling are included in Appendix 2b.

The modelling projected future suitable climatic zones, which could then be compared with current suitable climatic zones modelled from distribution records, 1950-2000 (Appendix 2a).

Changes are observed at all time steps, for all species modelled, in some parts of their ranges.

However, detailed interpretation of the results has been conducted only for the region of Victoria covered by the six EAGA councils (Appendix 3). These results are summarised in Table 1 (a, b, c and d), on the following four pages.

	2020	2050	2080
Floodplain Riparian Woodland			
Eucalyptus camaldulensis			
Coprosma quadrifida	Slight expansion	Reduction	Expansion NE of Bay
Melaleuca ericifolia	Possible reduction	Reduction	Reduction across most of region
Phragmites australis		Reduction	Contraction to the E
B			
Grassy Woodland			
Eucalyptus ovata		Strong reduction across the region	Unsuitable across region
E. viminalis		Reduction N of Bay	Becoming patchy, contracting to NE
B			
Plains Grassy Woodland			
Themeda triandra			
B			

Table 1a: Summary of interpretation of the results of bioclimatic modelling for EVCs in the City of Boroondara

LGAs
B = City of Boroondara
K = City of Knox
Ma = City of Maroondah
Mo = City of Monash
W = City of Whitehorse
YR = Yarra Ranges Council

Notes
Bay = Port Phillip Bay
GDR = Great Dividing Range

No entry indicates no projected change in the EAGA region.

No relevant change indicates that projected change will probably only affect areas where the species is not present or significant.

	2020	2050	2080
Swampy Woodland			
Eucalyptus obliqua		Reduction across the region	Becoming patchy, contracting to NE
E. ovata		Strong reduction across the region	Unsuitable across region
E. cephalocarpa			Some reduction around Bay
Melaleuca ericifolia		Reduction across the region	Contracting to the E
Phragmites australis			
K Mo W			
Valley Heathy Forest			
Eucalyptus macrorhyncha			No relevant change
Acacia melanoxylon			Reduction across the region
Themeda triandra			
K Mo W			
Swampy Riparian Woodland			
Eucalyptus ovata		Strong reduction across the region	Unsuitable across region
Acacia melanoxylon			Reduction across the region
Coprosma quadrifida	Reduction in W	Reduction	Reduction across most of region
Melaleuca ericifolia		Reduction across the region	Contracting to the E
Dicksonia antarctica		Reduction N of Bay	Reduction across most of region
Phragmites australis			
K Mo W			
Grassy Forest			
Acacia melanoxylon			Reduction across the region
Tetrarrhena juncea	Possible reduction in W	No change in E of region	Reduction across most of region
Themeda triandra			
K YR			

Table 1b: Summary of interpretation of the results of bioclimatic modelling for EVCs in the Cities of Knox, Monash and Whitehorse and the Shire of Yarra Ranges

	2020	2050	2080
Grassy Dry Forest			
Eucalyptus macrorhyncha			No relevant change
E. melliodora	Some reduction in W	No relevant change	Reduction across most of region
Exocarpos cupressiformis			
Themeda triandra			
Ma YR			
Damp Forest			
Eucalyptus cypellocarpa		Reduction across most of region	Further contraction to NE
E. obliqua		Reduction across the region	Becoming patchy, contracting to NE
Coprosma quadrifida	Possible reduction in W	No change in E of region	Reduction across most of region
Tetrarrhena juncea	Possible reduction in W	No change in E of region	Reduction across most of region
YR			
Herb-rich Foothill Forest			
Eucalyptus obliqua		Reduction across the region	Becoming patchy, contracting to NE
Themeda triandra			
YR			
Lowland Forest			
Eucalyptus obliqua		Reduction across the region	Becoming patchy, contracting to NE
Acacia melanoxylon			Reduction, contracting to the E
YR			
Riparian Forest			
Eucalyptus obliqua		Reduction across the region	Becoming patchy, contracting to NE
E. viminalis		Reduction N of Bay	Becoming patchy, contracting to NE
E. regnans	Strong reduction	Possible temporary expansion	Strong contraction into GDR
Acacia dealbata			
A. melanoxylon.			Reduction across the region
YR			

Table 1c: Summary of interpretation of the results of bioclimatic modelling for EVCs in the City of Maroondah and the Shire of Yarra Ranges

	2020	2050	2080
Shrubby Foothill Forest			
Eucalyptus obliqua		Reduction across the region	Becoming patchy, contracting to NE
Spyridium parvifolium			Reduction across the region
Tetrarrhena juncea	No relevant change	No relevant change	Reduction across most of region
YR			
Wet Forest			
Eucalyptus cypellocarpa		Reduction across most of region	Reduction across most of region
E. obliqua		Reduction across the region	Becoming patchy, contracting to NE
E. viminalis		Reduction N of Bay	Becoming patchy, contracting to NE
Acacia dealbata			
A. melanoxylon	Possible reduction in W		Reduction across the region
Olearea argophylla		Reduction across most of region	Reduction across most of region
Dicksonia Antarctica	No relevant change	Reduction N of Bay	Reduction across most of region
Tetrarrhena juncea.		No change in E of region	Reduction across most of region
YR			
Valley Grassy Forest			
Eucalyptus melliodora	Some reduction in W	May be slight expansion in W	Reduction across most of region
E. rubida	Reduction across most of region	Reduction across much of region	Unsuitable across most of region
Themeda triandra			
YR			

Table 1d: Summary of interpretation of the results of bioclimatic modelling for EVCs in the Shire of Yarra Ranges

LGAs
B = City of Boroondara
K = City of Knox
Ma = City of Maroondah
Mo = City of Monash
W = City of Whitehorse
YR = Yarra Ranges Council

Notes
Bay = Port Phillip Bay
GDR = Great Dividing Range

No entry indicates no projected change in the EAGA region.

No relevant change indicates that projected change will probably only affect areas where the species is not present or significant.

Limitations – In the following discussion, it is assumed that the more suitable the climate is for a species, the more the four bioclimatic models used will agree that it is suitable. Therefore increasing agreement on suitability by the models is interpreted as a proxy for increasing suitability. It can be seen from the maps of current distribution and climatic range in Appendix 2a, that no species occupies all of the range that appears to be climatically suitable. There will be other environmental factors, such as physical boundaries (mountains, rivers), competition and predation, that affect a species' distribution within its climatic envelope. It cannot be assumed that expansion of the suitable climatic zone in the future will necessarily result in expansion of a species' distribution. Nor can it be assumed that contraction of the suitable zone must result in a reduced distribution, especially where long-lived trees are already established. Monitoring and further research will be needed to verify these projections.

Discussion

All species affected

- Responses variable but all species are affected in some parts of their ranges
- General trend in the EAGA region to shift toward the North-East

As stated, the computer modelling projected changes in the distribution of suitable climatic zones, at all time steps, for all species modelled, in some parts of their ranges. Some, e.g. *Eucalyptus rubida,* show consistent reduction in suitable area at each time step.

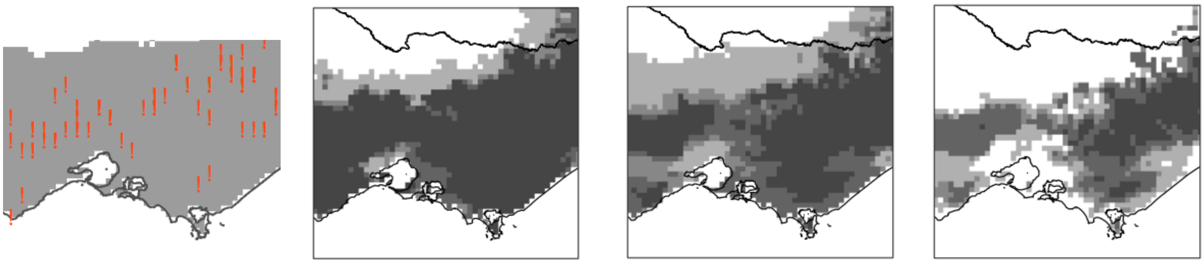

Figure 1 – The modelled climatic ranges in Central Victoria of Eucalyptus rubida, (from left) Current, 2020, 2050 and 2080. The red marks in the first map indicate AVH distribution records. The darker colours in the maps indicate higher climatic suitability across the four future climate scenarios examined.

Not all observed changes were unidirectional. The suitable zones for some species were projected to expand (2020) and later contract (2050) e.g. *Eucalyptus camaldulensis*, while *Eucalyptus regnans* contracts (2020), then expands (2050), only to contract again (2080).

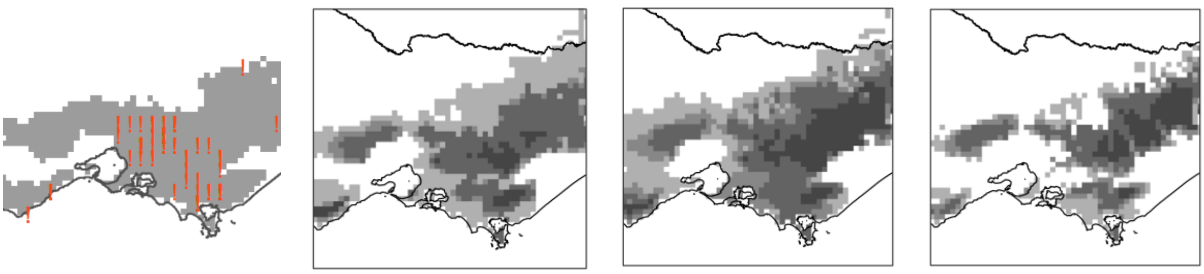

Figure 2 – The modelled climatic ranges in Central Victoria of *Eucalyptus regnans,* (from left) Current, 2020, 2050 and 2080. The red marks in the first map indicate AVH distribution records.

There is great variability in response between species, with some showing relatively small changes, e.g. *Themeda triandra*, while others show dramatic change, e.g. *Eucalyptus ovata*. The rate of change is also variable over time. For instance *E. ovata* shows little change by 2020 but by 2050 a strong reduction is indicated and by 2080 the EAGA region is projected to retain no areas with a suitable climate for the species.

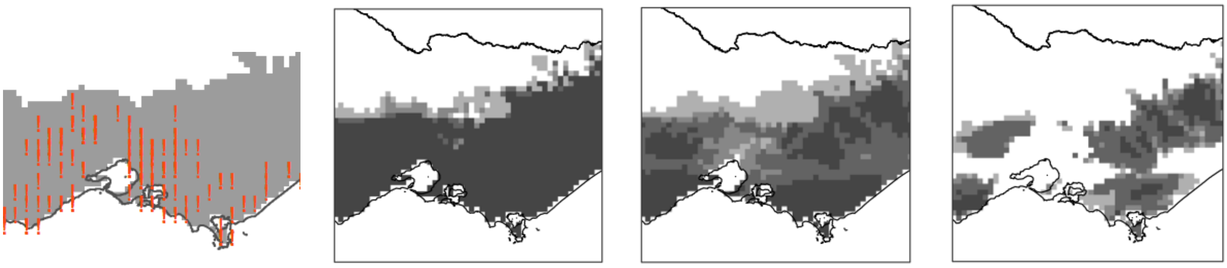

Figure 3 – The modelled climatic ranges in Central Victoria of *Eucalyptus ovata,* (from left) Current, 2020, 2050 and 2080. The red marks in the first map indicate AVH distribution records.

In the literature there are many references to a general migration of species towards higher latitudes and/or altitudes in response to climate change. The modelling conducted for this study does not indicate such general southward movement of the climatic zones, as might be expected. The projected movements in the EAGA region tend to be more toward the North-East, (as may be seen in Figures 1, 2 and 3, above) which may be related to the increasing altitude of the Great Dividing Range in this area. However these results might also reflect other changes, such as shifts in patterns of precipitation. Further research would be needed to elucidate the relative importance of these effects.

Effects on species

- Most change is often observed at extremes of distribution, outside EAGA region
- Strong change indicated for *Eucalyptus ovata* and *Eucalyptus rubida*
- Few species show no change in the EAGA region, some show little change

The EAGA region is located towards the South-East of the Australian mainland. The species modelled were selected for their ecological importance in the region, so it may be expected that the greatest projected changes in climatic suitability often occur outside the region, at the farthest extremes of the species' ranges, to the North (NSW and Queensland) and to the West (Western Australia and South Australia), e.g. *Eucalyptus obliqua, Exocarpos cupressiformis* and *Melaleuca ericifolia*. Conversely, the least change in suitability is often observed in the EAGA region and this is probably a function of the selection of species with distributions centred in this region.

Nevertheless the modelling has revealed potential changes in climatic suitability for several species that occur within the six LGAs. The species that shows the greatest effect in the short term (2020) is *Eucalyptus regnans*, for which only one model projects a suitable climate across much of the region at this time step (Figure 2). However the significance of this change is not clear. All four models agree on the retained suitability of the climate on the Great Dividing Range in the North-East, which is where the Mountain Ash forests of the Central Highlands are found.

Over all time steps, the species which demonstrate the greatest, and potentially the most significant, changes are *Eucalyptus ovata* (Figure 3) and *E. rubida* (Figure 1). *E. ovata* is currently distributed across the EAGA region but by 2080 all models agree that there will be no remaining climatically suitable area for the species. (*E. ovata* is the Floral Emblem of the City of Maroondah.) Similarly, the suitable range for *E. rubida* is projected to contract from across the region into the far North-East, with all models agreeing that most of the region will be unsuitable for the species by 2080.

These changes in climatic suitability will not necessarily result in the loss of those species from the area. Established plants, especially large trees, may be resilient to change, at least in the early stages. However there may be effects on the health and reproduction of such plants with the recruitment and establishment phases being when there may be greatest vulnerability to environmental changes. Seedling establishment on the contracting range boundaries of affected species may therefore provide an early indicator of change that is not apparent in established populations. This may be an effective way of tracking climate change response.

Only a few species show no change in climatic suitability in the EAGA region; a tree, *Acacia dealbata* (Figure 4), two shrubs, *Spryridium parvifolium*, *Exocarpos cupressiformis*, a grass, *Themeda triandra*, and the reed, *Phragmites australis*.

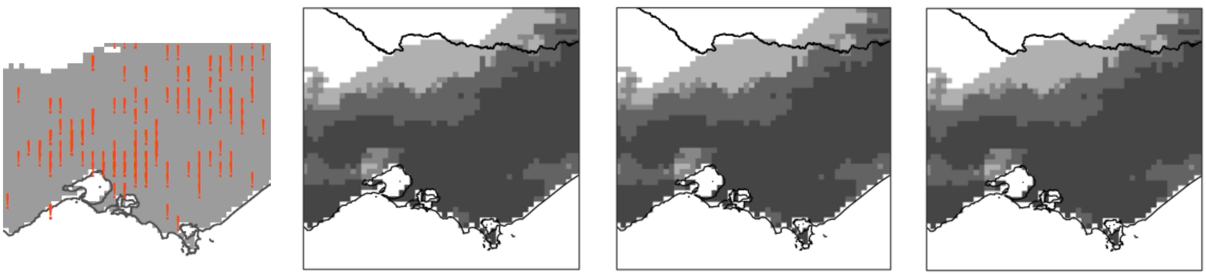

Figure 4 – The modelled climatic ranges in Central Victoria of *Acacia dealbata,* (from left) Current, 2020, 2050 and 2080. The red marks in the first map indicate AVH distribution records.

Other trees that show little effect are *Eucalyptus macrorhycha, E. cephalocarpa* and *Acacia melanoxylon*, which show no change in the region to 2050 (all four models agreeing climatic suitability) but reducing (to three) in part of the region by 2080.

Effects on EVCs

- Species in an EVC appear to respond independently of each other, not together

In Table 1, the results of the bioclimatic modelling for species are grouped according to the Ecological Vegetation Classes (EVCs) in which they occur. Several species within an EVC may appear to change more or less together e.g. Damp Forest (2080, Figure 5).

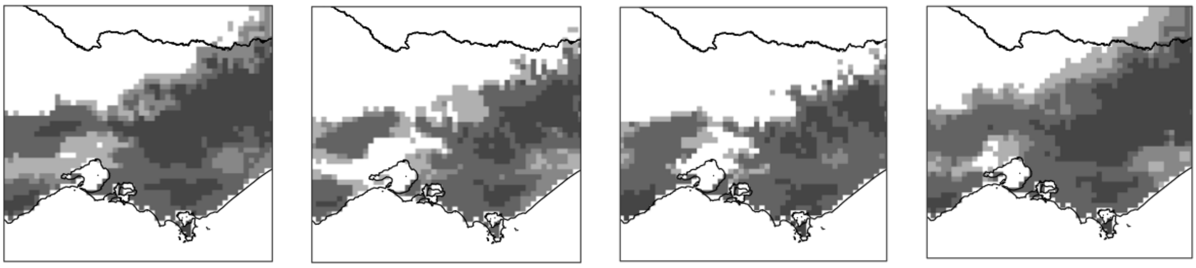

Figure 5 – The modelled climatic ranges in Central Victoria of species in Damp Forest EVC in 2080 (from left), *Coprosma quadrifida, Eucalyptus cypellocarpa, E. obliqua and Tetrarrhena juncea.*

However, this is not necessarily the case. For instance in Swampy Woodland (2050), while there is strong reduction in *Eucalyptus ovata*, there is no change in *E. cephalocarpa* (Figure 6). Suggesting that even species in the same genus may not necessarily respond in a similar way to future climate change. These species may occupy different ranges across Australia, which may drive differences in the models and result in different projections for these closely related species. Further work would be needed to identify such effects.

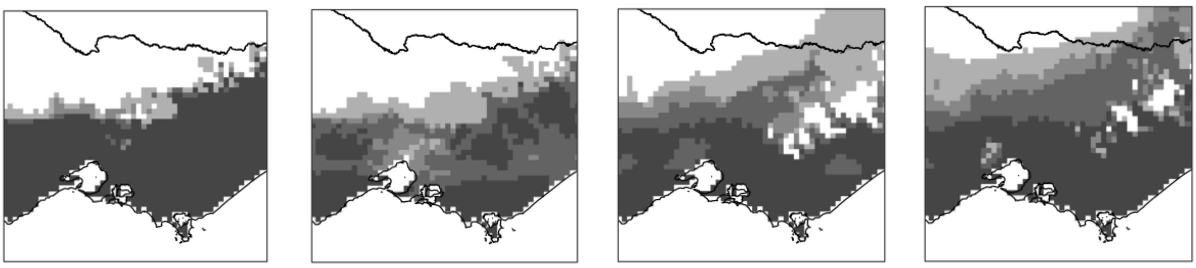

Figure 6 – The modelled climatic ranges in Central Victoria of species in Swampy Woodland EVC (from left), *Eucalyptus ovata* 2020*, E. ovata* 2050*, E. cephalocarpa* 2020 *and E. cephalocarpa* 2050*.*

Vulnerability of EVCs

- It may be possible to rank EVCs according to vulnerability to climate change

If it is assumed that EVCs that contain one or more ecologically important species whose climatically suitable ranges are projected to significantly reduce, are likely to be at increased risk in a changing climate, it becomes possible to construct a hierarchy of EVCs ranked according to their vulnerability to the effects of global warming. Such an arrangement may be of some value to Local Governments in deciding where to direct limited resources in managing biodiversity under their jurisdictions.

On the basis of the modelling conducted for this study, such an arrangement for the EAGA region might appear as follows.

<u>EVCs of greatest concern</u>
Grassy Woodland (City of Boroondara)
Swampy Woodland (Cities of Knox, Monash and Whitehorse)
Swampy Riparian Woodland (Cities of Knox, Monash and Whitehorse)
Valley Grassy Forest (Yarra Ranges Council)

<u>EVCs of significant concern</u>
Damp Forest (Yarra Ranges Council)
Herb-rich Foothill Forest (Yarra Ranges Council)
Lowland Forest (Yarra Ranges Council)
Riparian Forest (Yarra Ranges Council)
Shrubby Foothill Forest (Yarra Ranges Council)
Wet Forest (Yarra Ranges Council)

<u>EVC of concern</u>
Floodplain Riparian Woodland (City of Boroondara)

<u>EVCs of least concern</u>
Plains Grassy Woodland (Boroondara)
Valley Heathy Forest (Cities of Knox, Monash and Whitehorse)
Grassy Forest (City of Knox, Yarra Ranges Council)
Grassy Dry Forest (City of Maroondah, Yarra Ranges Council)

Conclusions and recommendations

The projections show that all species modelled are likely to be affected in at least some parts of their range by a changing climate during the 21st century. It will therefore be important to monitor all EVCs for early signs of changing populations. Such early indicators may include changes in seedling establishment. Baseline data needs to be established so that any changes can be identified. Species of particular concern in the EAGA region are *Eucalyptus ovata, E. rubida* and *E. regnans*.

The modelling conducted for this study confirms that species that currently occur together in particular habitats, and are therefore grouped together into EVCs, nevertheless may have different climatic ranges and are likely to respond to changes independently of each other, not necessarily in association. These different responses could lead to changes in the composition of existing EVCs, the loss of some and possibly the emergence of new communities.

Local government authorities will need to develop policies regarding the valuing and maintenance of EVCs in their jurisdiction. They will need to consider whether intervention is necessary, desirable and/or possible to maintain some EVCs and in what circumstances intervention would be considered.

This study has shown that bioclimatic modelling could be valuable in projecting the potential effects of climate change on species and EVCs. This may assist councils in allocation of resources to manage and preserve bushland and biodiversity values.

Monitoring for indications that species' distributions and EVC compositions are changing will be needed.

Contributors to this Case Study

EAGA thanks all those who, through their advice, support and participation, contributed to the success of this study –

Cynnamon Dobbs Brown (ARCUE),
Rachael V. Gallagher (Macquarie University),
Lee Harrison (ARCUE),
Lesley Hughes (Macquarie University),
Graeme Lorimer (Biosphere P/L),
Rodney van der Ree (ARCUE),
Darren Wallace (Knox Environment Society),
Nicholas Scott Williams (University of Melbourne)

Members of the EAGA Project Steering Committee

Appendices

Appendix 1 – Selecting plant species for climate modelling (Rodney van der Ree, 2011)

Appendix 2a - Current distributions and modelled climatic envelopes (1950 – 2000), (Rachael Gallagher, 2011)

Appendix 2b – Projected climatically suitable habitat for urban bushland species under climate change (Rachael Gallagher, 2011)

Appendix 3 - Interpretation of bioclimatic modelling results grouped by EVC and arranged by LGA

References

CSIRO, **Climate Futures for Eastern Melbourne**, Data provided for the Eastern Alliance for Greenhouse Action, July 2010

Hughes, Lesley, Cawsey, E.M. and Westoby, Mark, **Climatic range sizes of *Eucalyptus* species in relation to future climate change**, Global Ecology and Biogeography Letters, 1996

Nitschke, C.R. and Hickey, G.M., **Assessing the vulnerability of Victoria's Central Highland forests to climate change**, Technical Report. Peer reviewed and unpublished. 2007