Climate change: the adaptation/mitigation challenge

Dr Colin Yates

Science Division

Department of Environment and Conservation

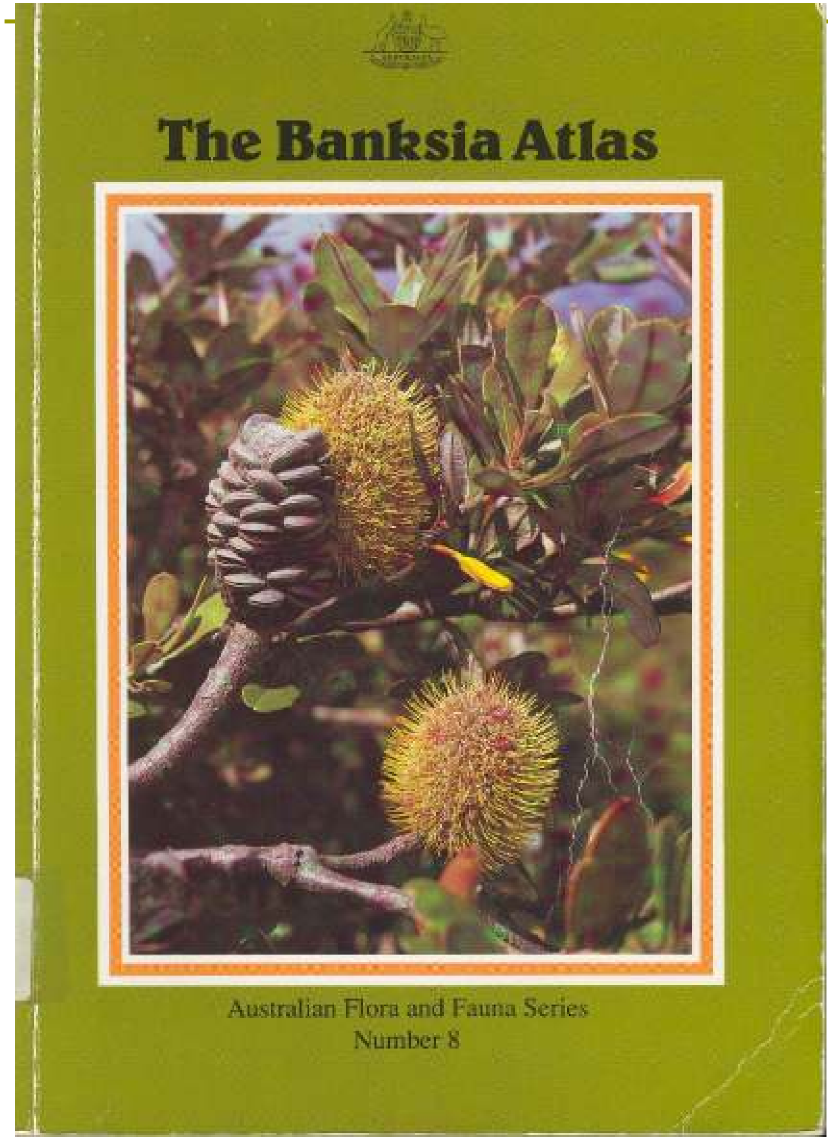
Department of
Environment and Conservation

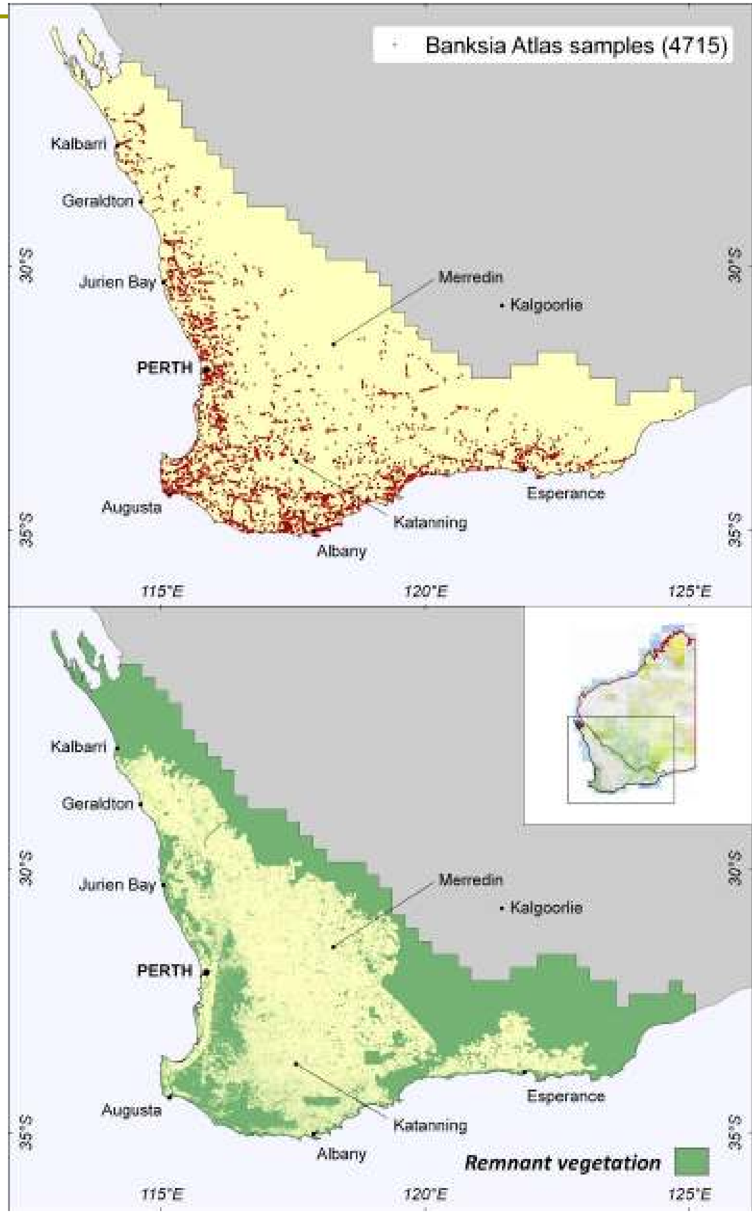
Our environment, our future

Acknowledgements

- Department of Climate Change – Bilateral Climate Change Partnerships Program
- Margaret Byrne, Lesley Gibson, Asha McNeill, Paul de Torres, Adrian Wayne - DEC
- Jane Elith – Melbourne University
- Neal Enright , Amity Williams, Phil Ladd - Murdoch University
- Ray Froend – Edith Cowan University
- Steve Hopper – Royal Botanic Gardens,Kew
- Guy Midgley - South African National Biodiversity Institute
- Kimberly van Niel – University of Western Australia
- Grant Wardell-Johnson, Gunnar Keppel, Laco Mucina, Tom Schutt - Curtin University

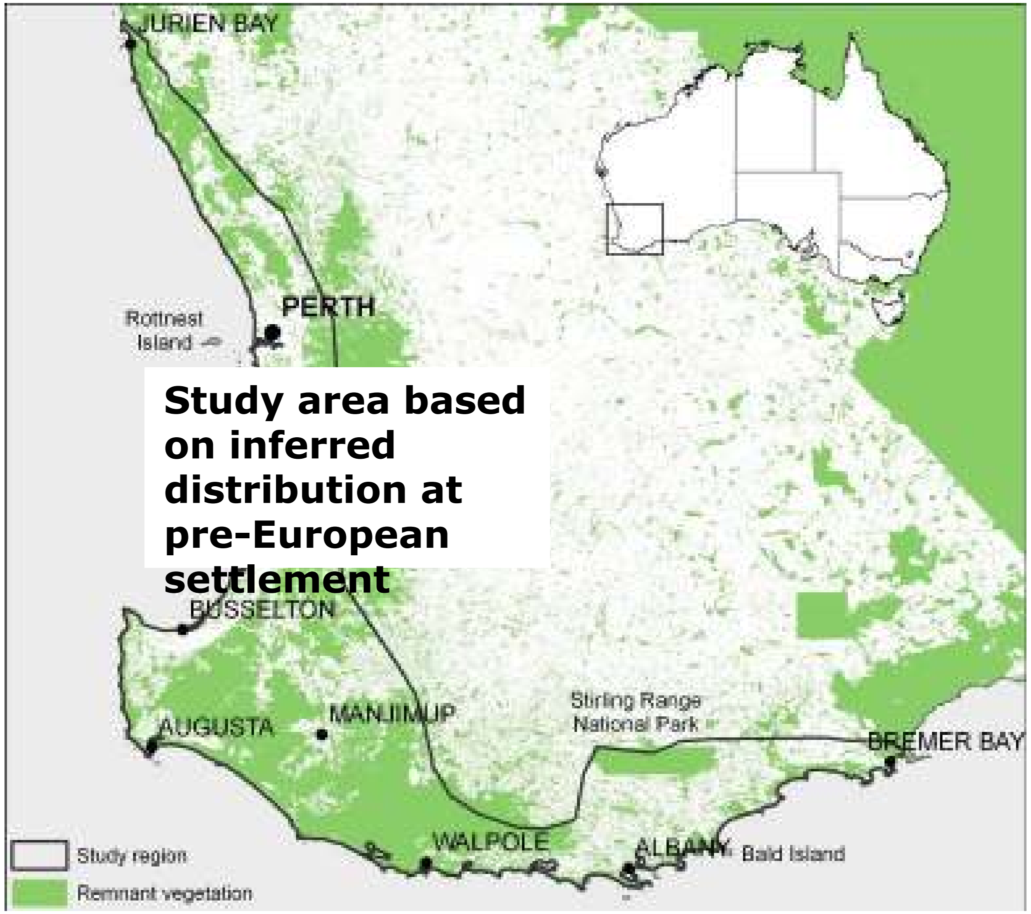
Utilizing existing biodiversity datasets for risk assessment
Projecting impacts of climate change and land transformation on Banksia





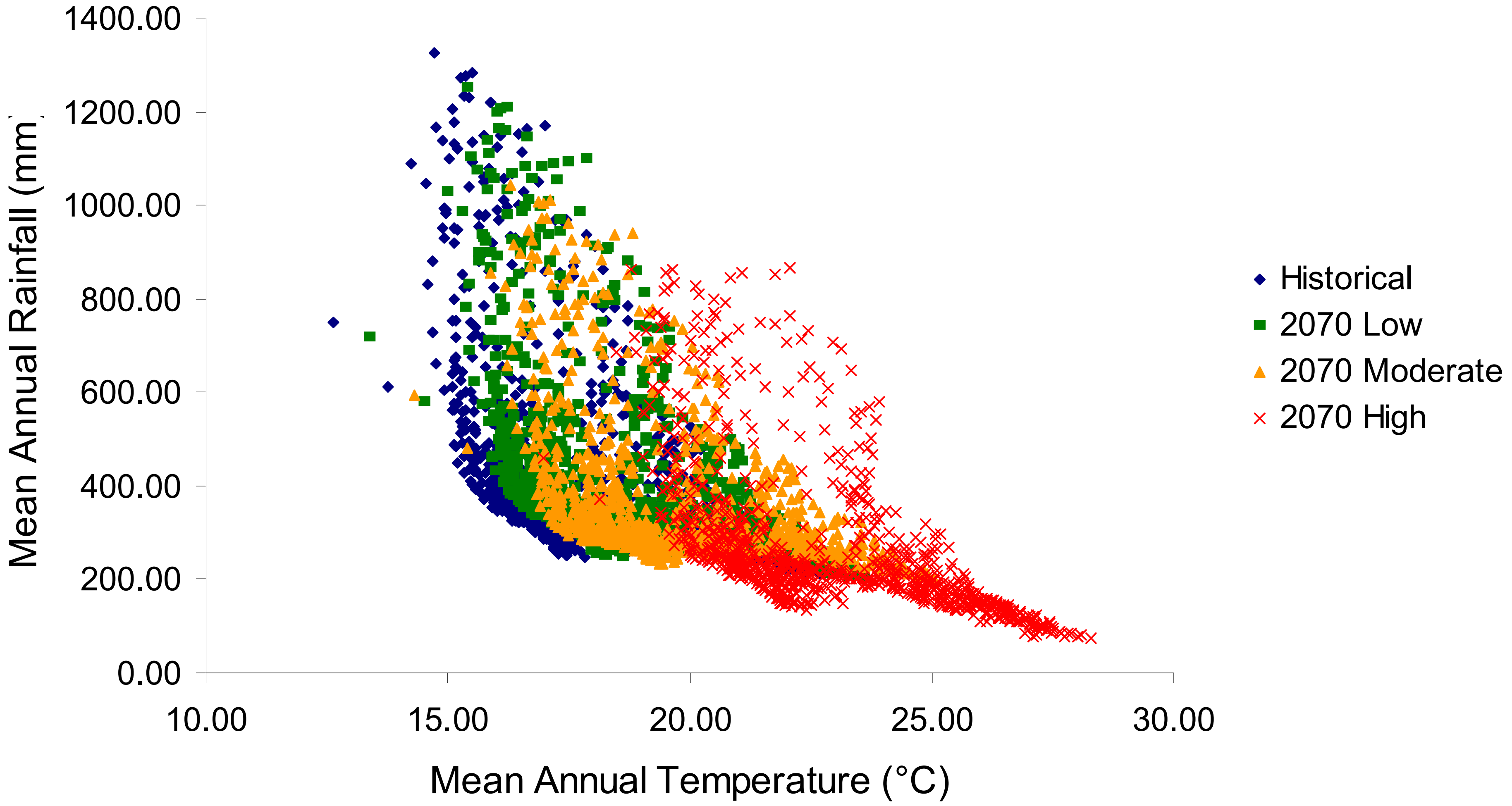
Yates CJ, McNeill A, Elith JE Midgley GF (2010) Diversity & Distributions, 16, 187-201.

The quokka *Setonix brachyurus*

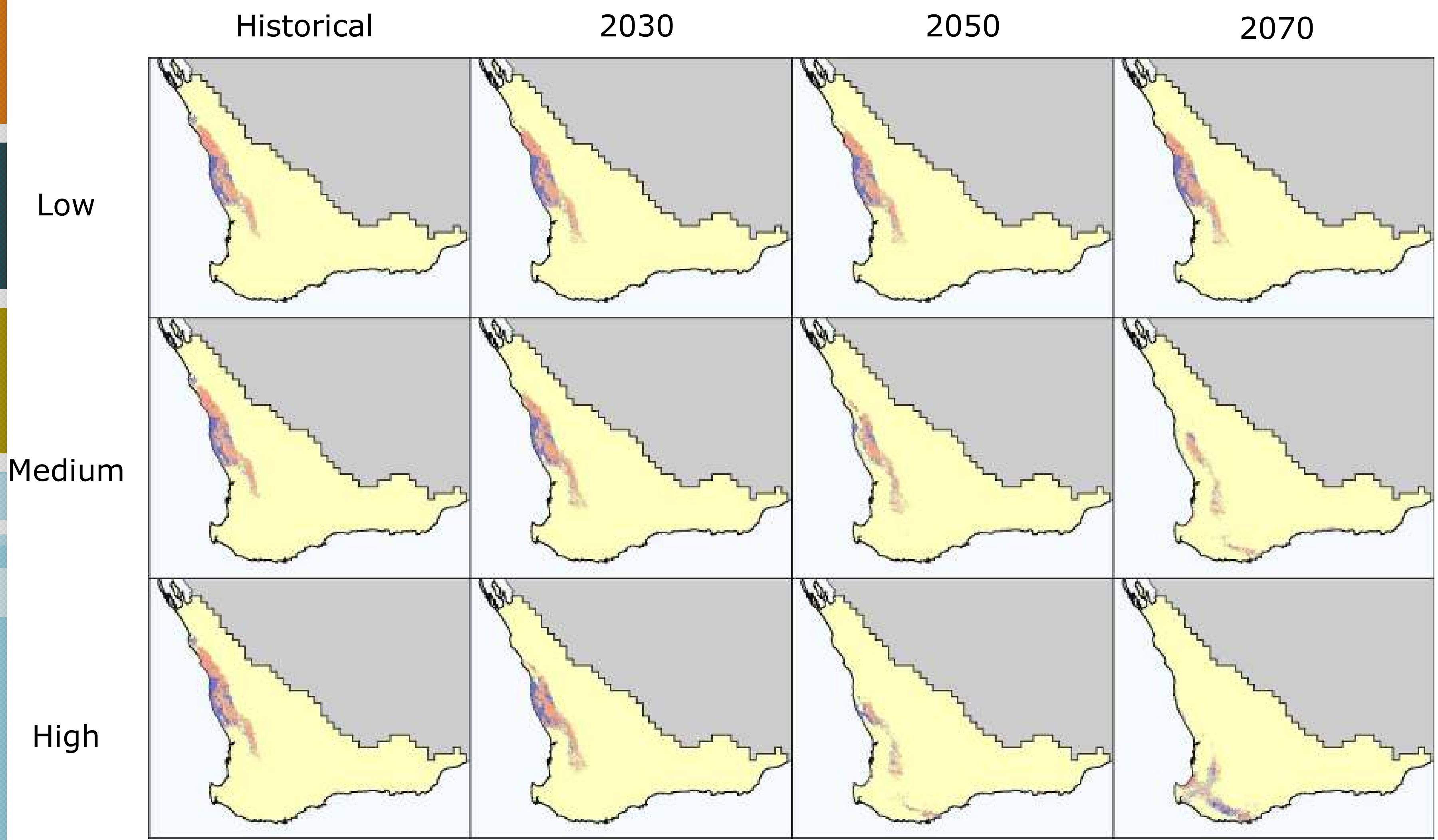


Study area based on inferred distribution at pre-European settlement

Modeled mean annual rainfall v. mean annual temperature at 1000 points across SWWA for historical period (1961-90) and three climate impact scenarios in 2070

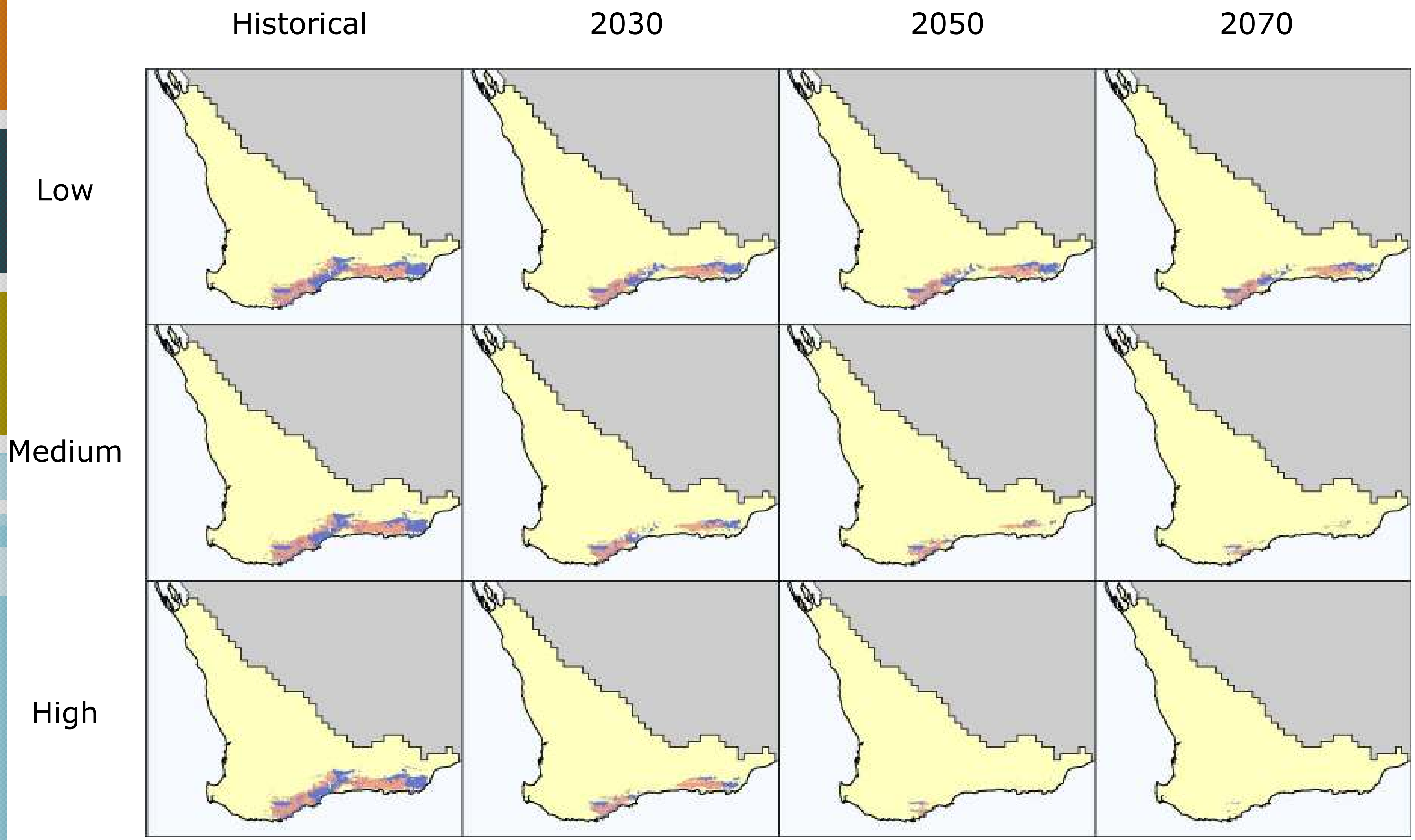


Projected geographic ranges of *Banksia leptophylla* for three climate change severity scenarios

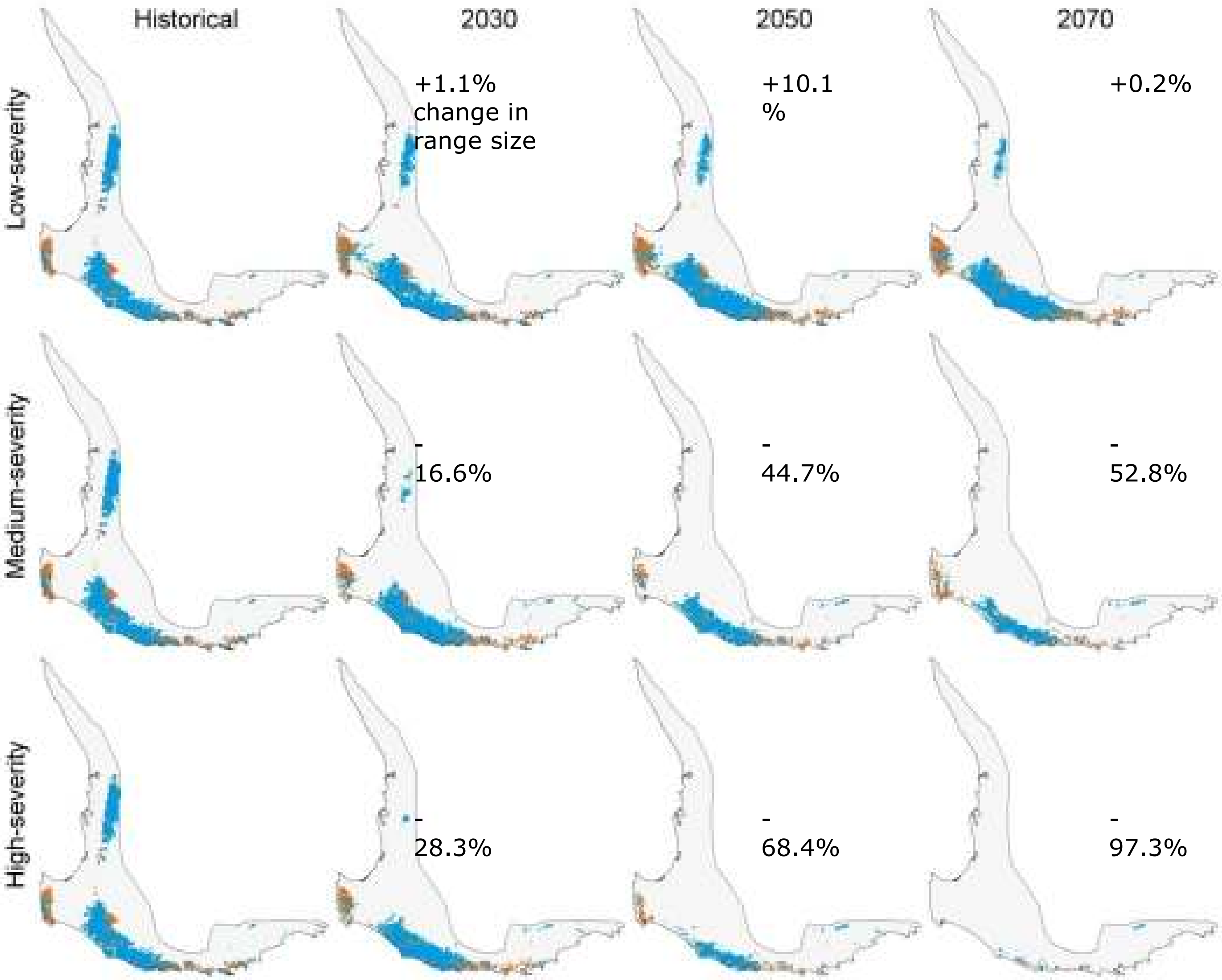


Yates C.J., McNeill A., Elith J., Midgley G.F. (2010). Assessing the impacts of climate change and land transformation on *Banksia* in the Southwest Australian Floristic Region. *Diversity and Distributions*, **16**, 187-201.

Projected geographic ranges of *Banksia gardneri* for three climate change severity scenarios



Projected geographic ranges of Quokka for three climate change severity scenarios



Gibson L., McNeill A., de Torres P., Wayne A., Yates C.J. (2010). Will future climate change threaten a range restricted endemic species, the quokka (Setonix brachyurus), in south west Australia? *Biological Conservation*, 143, 2453-2461.

Terms and conditions for interpreting species distribution model output

- Although SDM's are increasingly used to forecast the impacts of climate change on species distributions, their evaluation (validation) remains problematic, because there are seldom suitable data against which predictions of future ranges can be tested. Consequently, evaluation of models is usually restricted to how well they predict current distributions (but see Araujo *et al.* 2005). Evaluations of current distributions preferably use an independent data set, but in reality most often use data re-substitution or data splitting, whereby a portion of the data are used to train the model and a portion withheld to validate it. Two measures of classification accuracy are commonly used, the Kappa statistic and the area under the curve (AUC) of a receiver operating characteristic (ROC) plot (Guisan & Zimmerman 2000; Guisan & Thuiller 2005; Heikkinen *et al.* 2007). The Kappa co-efficient measures the correctly classified presences and absences after the probability of chance agreement has been removed. The AUC of the ROC plot reports whether predictions are well ranked (i.e. predictions for presence sites being higher than predictions for absence sites) over all possible threshold levels. Other more subjective methods can also be used to evaluate models, including expert interpretation of the model to check its consistency with knowledge of the species (Austin 2002).
- Predictive accuracy may vary considerably among different modelling methods applied to the same data set (Thuiller 2003, 2004; Araújo *et al.* 2005; Elith *et al.* 2006; Pearson *et al.* 2006; Lawler *et al.* 2006). However, because the models are correlative, strong performance of any method in the present climate does not guarantee similar performance under future climates (Thuiller 2004, see discussion below), especially as biotic interactions may change due to species within current communities responding differently to climate change (Davis *et al.* 1998; Pearson and Dawson 2003).
- Uncertainties in future species distributions arising from variation in predictions among different SDM methods, different GCMs, and emission scenarios can at least be quantified and incorporated into a range of conditional probabilities. More problematic are uncertainties in model predictions arising from the genetic, life-history, ecological and historical factors, which in addition to climate influence species distributions (Lewis 2006).
- With the exception of recent Bayesian models most SDMs assume species are at equilibrium with the present climate, and most use just bioclimatic variables to predict the present and future distributions of species under climate change. As a consequence SDMs have been criticized for not including key processes affecting species distributions, and have been seen as over simple, yielding misleading predictions (Hampe 2004; Lewis 2006).
- Species distribution models rely on the assumption that a species is currently at equilibrium with the present climate and the models extrapolate this equilibrium assumption into the future to generate potential range forecasts. This is problematic because past events (e.g. climate at the Last Glacial Maximum LGM), together with the migration ability of species, will influence their present distribution (Svenning & Skov 2007). Species with limited migration ability or whose ranges are restricted by physical barriers to migration may take a long time to reach a new future equilibrium with climate (e.g. Leathwick 1998), and for all species that are not at equilibrium with climate (e.g. because they are still in a phase of expansion since the LGM), correlative range distribution forecasts will inevitably be biased. In this case any method of consensus/ensemble forecasting will only summarize these biased projections.
- All species exist within a web of mutualistic and antagonistic interactions with other species, and numerous studies have demonstrated how the presence or absence of one species can affect the population and range dynamics of another (Connell 1961; Davis *et al.* 1998; Leathwick & Austin 2001). An acknowledged shortcoming of single species SDMs is that they do not explicitly account for the effects of biotic interactions on species distributions. Negative interactions (e.g. inter-specific competition), positive interactions (e.g. mutualisms) and meta-population source-sink dynamics may alter species distributions (Hutchinson 1957; Shmida & Ellner 1984; Araújo & Guisan 2006). Thus what appears to be a climatic limit to a species range may be a biotic interaction with, for example a competing species. This may not be a weakness for predicting species distributions under present conditions. Indeed, many SDMs utilizing only bioclimatic variables predict present species distributions reasonably well. However, neglecting inter-specific interactions may result in incorrect predictions of future distributions if biotic interactions change (Davis *et al.* 1998; Pearson & Dawson 2003), and this will be influenced by the stability of assemblages of interacting species.
- Although the distribution of species assemblages can often be predicted by environmental variables, the fossil record indicates that in many areas these assemblages may not be stable in geological time. Species apparently respond idiosyncratically to climate change, because of differential persistence, dispersal rates and substrate affinities. As a consequence novel species assemblages and interactions will develop in the future. A question which arises from the foregoing is: how will a new community context affect the population and range dynamics of a species or, put another way, how stable are modelled niches in the face of changing species assemblages? Species distribution models assume niche conservatism. Some authors argue that rearrangements of species interactions will have effects on population and range dynamics far greater than those arising directly from the influence of climate change on species physiological tolerances (Davis *et al.* 1998). Other authors argue that bioclimatic envelopes remain stable through time (Peterson *et al.* 2005; Martínez-Meyer & Peterson 2006). The reality probably lies somewhere in between. There are a growing number of experimental and empirical studies which demonstrate that climate change can affect the strength and direction of existing inter-specific interactions and so profoundly affect the population dynamics of species and alter the composition of ecosystem (Suttle *et al.* 2007). The legacy of long-lived species with adult stages that can persist, but are unable to recruit as the climate changes, may prevent colonizing species from establishing. Currently, SDMs cannot forecast the lagged impacts of altered higher order species interactions that will govern the trajectory of ecosystems. More systems oriented approaches will be necessary to elucidate these responses (Suttle *et al.* 2007).

Case study 2

Biodiversity

Predicting the impacts of climate change on biodiversity and ecosystem function in biodiverse shrublands

The Eneabba sandplain, located 300 kilometres north of Perth, Western Australia, is a world-renowned biodiversity hotspot, and supports native vegetation known as Kwongan — the Aboriginal word for low hard scrub and heathland. Kwongan of the Eneabba region is extremely diverse and contains many species, a large percentage of which are endemic to the region. As well as being biologically important, the area is popular among tourists and botanists who visit Eneabba during the wildflower season.

The sandplain soils have very low water holding capacity, and during the hot summer months dry out to considerable depth, rewetting in winter when rain falls. Many species survive the summer drought with deep root systems capable of accessing water held deep in the soil profile in unconsolidated aquifers, which recharge when winter rain falls. Other species are less reliant on groundwater and have alternative mechanisms for surviving Eneabba's hot and dry summers.

Since the mid 1970s, rainfall in south-west WA has declined, with less rain falling at the beginning of winter. The Indian Ocean Climate Initiative has attributed this in part to anthropogenic climate change, with further drying predicted to continue as greenhouse gases accumulate in the atmosphere. What impact will climate change have on the extraordinarily diverse plant species and communities that make up the Kwongan at Eneabba?

To answer this question scientists from the Department of Environment and Conservation, Murdoch and Edith Cowan universities, and The University of Western Australia have teamed up in a new project to investigate the relationship between climate, groundwater dynamics, plant ecophysiology and population dynamics (demography).

Specifically, the project will:

- quantify diurnal and seasonal patterns of water storage and distribution in the soil profile together with plant water use for a range of species in the Kwongan;
- quantify experimentally the effects of decreased winter rainfall and increased daytime temperatures on plant species' ecophysiology and demography to identify critical climate thresholds;
- analyse the evidence for climate-driven range contraction during the past 30 years among plant species of the Kwongan;
- develop and calibrate models linking climate soil water dynamics, plant water use and demographic response to predict future climate change impacts.

For more information contact Professor Neal Enright (n.enright@murdoch.edu.au) or Dr Colin Yates (colin.yates@dec.wa.gov.au).




Key points

- Planning for climate change a challenge because of uncertainty about the
  - magnitude and rate of climate change
  - climate tolerances and adaptive capacity of species
  - complex interactions among species
  - non-linear dynamics of ecosystems
- Credible scientific assessments of vulnerability are needed
- Only the most optimistic and least risk averse among us would consider that we shouldn't act
  - Urgent action is needed on mitigating greenhouse gas emissions
- But we are already committed to a certain amount of climate change and an increase of 2°C by the end of the century looks inevitable
- Consequently, there is an urgent need for initiatives and actions that reduce the vulnerability of natural and human systems against expected climate change impacts

Conservation strategies for a changing climate

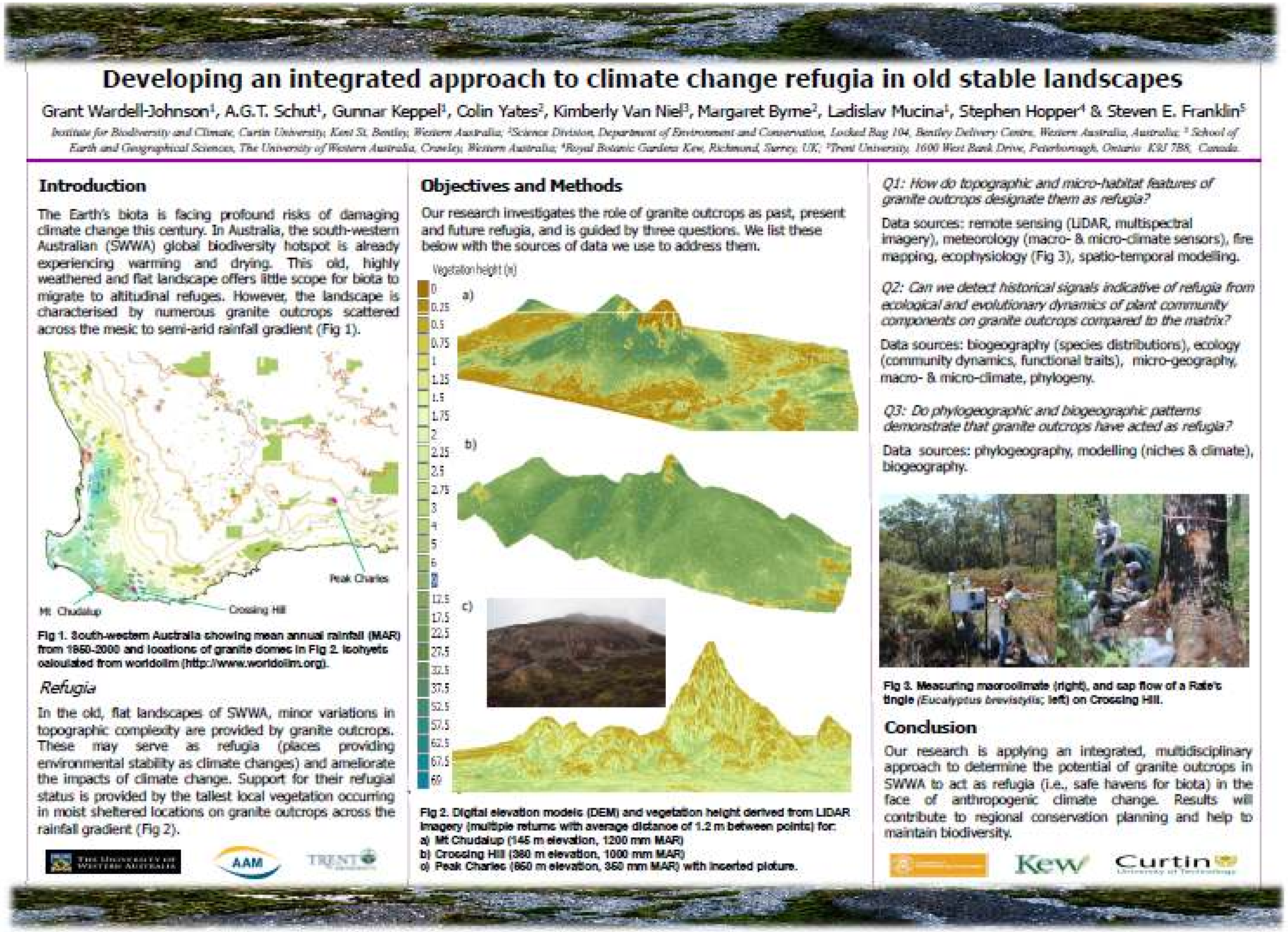
- Reducing emissions and ensuring bio-diverse carbon capture
- Managing our natural carbon sinks effectively
- Tackling existing stressors leading to biodiversity loss
- Strengthening off-reserve conservation
- Securing the reserve system
- Establishing appropriate ecological connectivity
- Identifying areas that may act as climate change refuges
- Increasing commitment to effective monitoring programs and climate change adaptation science
- Assisted migration
- Ex situ conservation

Steffen *et al*. 2009. Climate change and biodiversity: an adaptation response for Australia. CSIRO Publishing, Melbourne.

Reducing emissions and ensuring biodiverse carbon capture

- Carbon capture through revegetation of cleared agricultural land
- Additional benefits for biodiversity – habitat, increased connectivity

Identifying climate change refugia



Developing an integrated approach to climate change refugia in old stable landscapes

Grant Wardell-Johnson[1], A.G.T. Schut[1], Gunnar Keppel[1], Colin Yates[2], Kimberly Van Niel[3], Margaret Byrne[2], Ladislav Mucina[1], Stephen Hopper[4] & Steven E. Franklin[5]

[1]Institute for Biodiversity and Climate, Curtin University, Kent St, Bentley, Western Australia; [2]Science Division, Department of Environment and Conservation, Locked Bag 104, Bentley Delivery Centre, Western Australia, Australia; [3] School of Earth and Geographical Sciences, The University of Western Australia, Crawley, Western Australia; [4]Royal Botanic Gardens Kew, Richmond, Surrey, UK; [5]Trent University, 1600 West Bank Drive, Peterborough, Ontario K9J 7B8, Canada.

Introduction

The Earth's biota is facing profound risks of damaging climate change this century. In Australia, the south-western Australian (SWWA) global biodiversity hotspot is already experiencing warming and drying. This old, highly weathered and flat landscape offers little scope for biota to migrate to altitudinal refuges. However, the landscape is characterised by numerous granite outcrops scattered across the mesic to semi-arid rainfall gradient (Fig 1).

Fig 1. South-western Australia showing mean annual rainfall (MAR) from 1950-2000 and locations of granite domes in Fig 2. Isohyets calculated from worldclim (http://www.worldclim.org).

Refugia

In the old, flat landscapes of SWWA, minor variations in topographic complexity are provided by granite outcrops. These may serve as refugia (places providing environmental stability as climate changes) and ameliorate the impacts of climate change. Support for their refugial status is provided by the tallest local vegetation occurring in moist sheltered locations on granite outcrops across the rainfall gradient (Fig 2).

Objectives and Methods

Our research investigates the role of granite outcrops as past, present and future refugia, and is guided by three questions. We list these below with the sources of data we use to address them.

Fig 2. Digital elevation models (DEM) and vegetation height derived from LIDAR imagery (multiple returns with average distance of 1.2 m between points) for:
a) Mt Chudalup (145 m elevation, 1200 mm MAR)
b) Crossing Hill (380 m elevation, 1000 mm MAR)
c) Peak Charles (650 m elevation, 350 mm MAR) with inserted picture.

Q1: How do topographic and micro-habitat features of granite outcrops designate them as refugia?

Data sources: remote sensing (LIDAR, multispectral imagery), meteorology (macro- & micro-climate sensors), fire mapping, ecophysiology (Fig 3), spatio-temporal modelling.

Q2: Can we detect historical signals indicative of refugia from ecological and evolutionary dynamics of plant community components on granite outcrops compared to the matrix?

Data sources: biogeography (species distributions), ecology (community dynamics, functional traits), micro-geography, macro- & micro-climate, phylogeny.

Q3: Do phylogeographic and biogeographic patterns demonstrate that granite outcrops have acted as refugia?

Data sources: phylogeography, modelling (niches & climate), biogeography.

Fig 3. Measuring macroclimate (right), and sap flow of a Rate's tingle (*Eucalyptus brevistylis*; left) on Crossing Hill.

Conclusion

Our research is applying an integrated, multidisciplinary approach to determine the potential of granite outcrops in SWWA to act as refugia (i.e., safe havens for biota) in the face of anthropogenic climate change. Results will contribute to regional conservation planning and help to maintain biodiversity.

Translocations - Reintroductions WA Flora

- Currently 55 species (90 populations?) have been translocated-reintroduced
- *Ex situ* seed collections exist for, 1530 taxa (293 threatened) – 3258 collections
- A number have involved *Phytophthora* susceptible taxa translocated outside their known range
- Climate change issues are given little consideration