Climate adaptation and provenance choice for revegetation: Insights from *Eucalyptus*

Brad Potts

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1. Eucalypt populations exhibit a close adaptive response to their environment

LD Pryor **WD Jackson**

- local-scale
  e.g. altitudinal or edaphic
- broad-scale
  e.g. macro-climate

Pryor LD (1957) Proc. Linn. Soc. NSW 81: 299-305

Barber & Jackson (1957) Nature 179: 1267-1269

Numerous lines of evidence for climate adaptation

1. Correlative
   - evidence of divergent selection

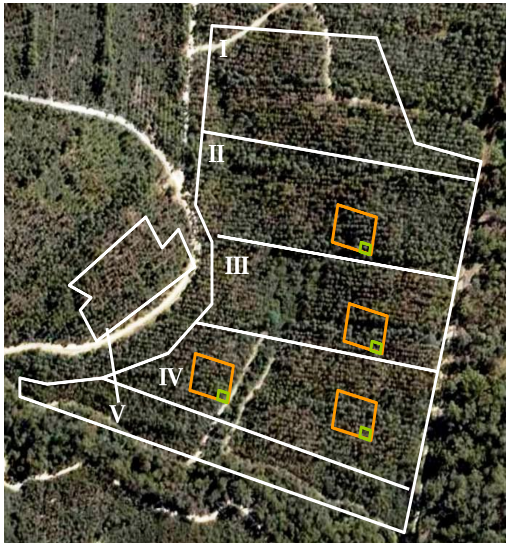
     e.g. divergence in functional trait (Q_{ST}) exceeds neutral molecular expectations (drift) (F_{ST})
   - plus correlated with spatial variation in climate
   - plus consistency with functional expectations

2. Direct (selection experiments)
   - laboratory/glasshouse
   - field trials:
     - *in situ* (e.g. reciprocal plantings in the wild)
     - *ex situ* (e.g. multi-site tree breeding trials)

Range-wide seed collections and testing in breeding trials: the case of *E. globulus*

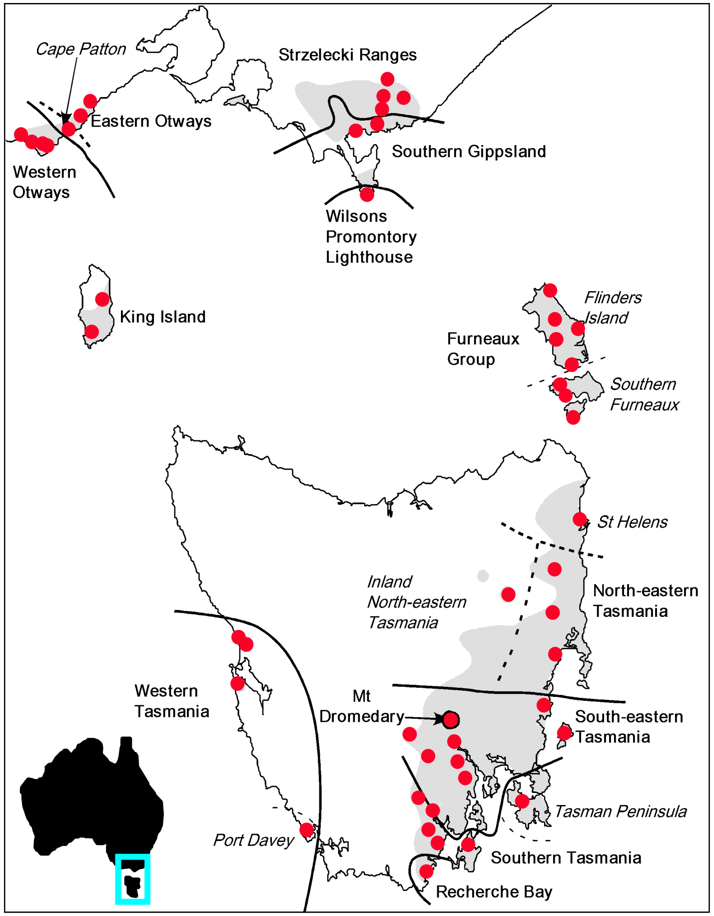
CSIRO 1987/88 base population seed collection

- 600+ open-pollinated families
- 46 localities



Trials designed with randomization at the family level (e.g. randomized incomplete block designs, 2 tree plots, 5 reps)

Sampling localities



Dutkowski and Potts 1999

Lopez *et al.* 2001

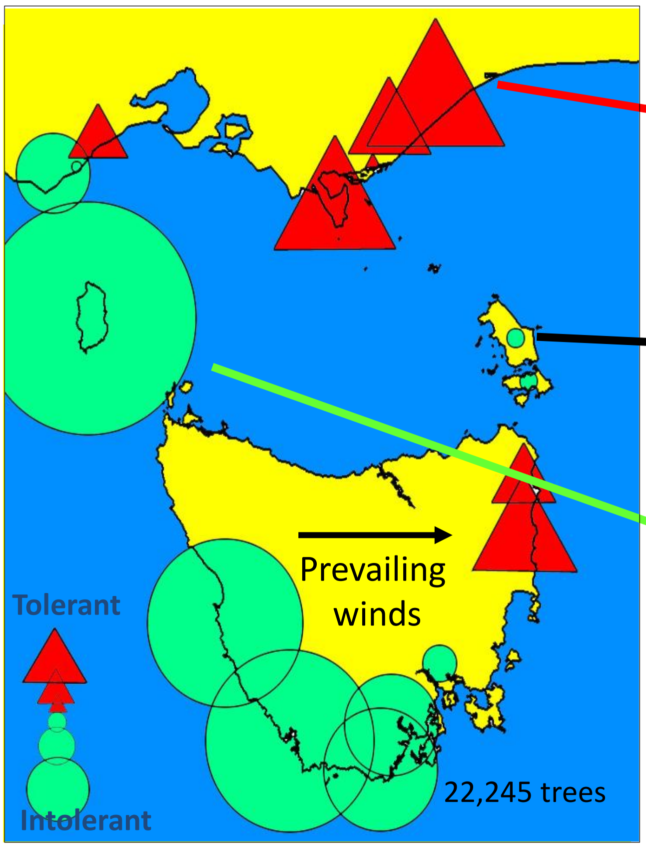
Seed lots from the 87/88 CSIRO collection of *E. globulus* have been tested globally

76 International trials
26 Australian trials

Potts *et al.* 2004

Home-site climate predicts susceptibility to drought and growth on dry sites

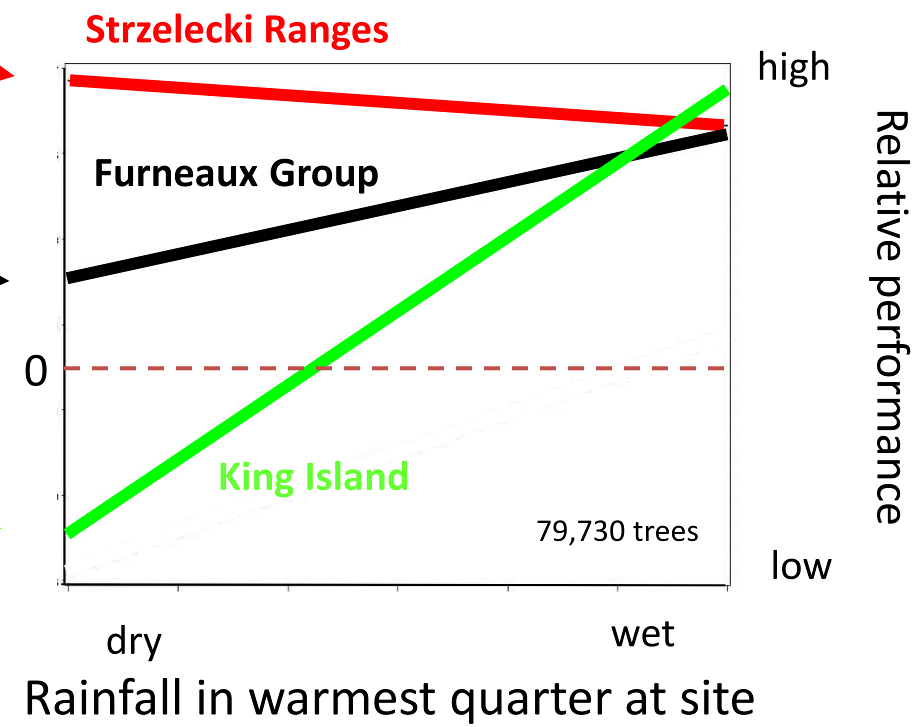
Drought tolerance



1993/4 drought damage in 4 WA trials (5 year old)

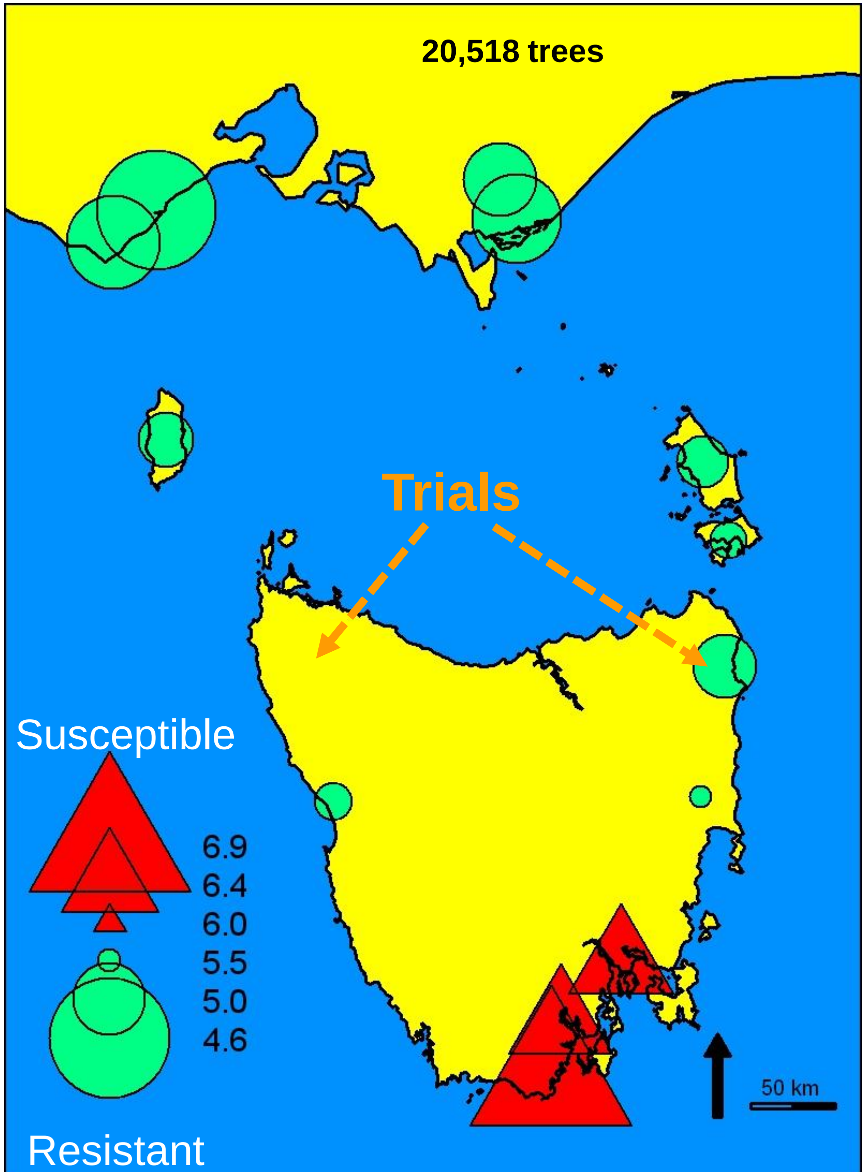
Dutkowski and Potts 2012 Tree Genetics & Genomes 8, 757–773.

Tree growth (dbh)



Costa e Silva *et al.* 2006 Tree Genetics and Genomes 2, 61-75.

Climate adaptation is multi-trait and involves selection by both abiotic and biotic factors



% juvenile foliage damaged in 2007 in 4 field trials in Tasmania

Hamilton *et al.* 2013, Heredity 110, 372–379

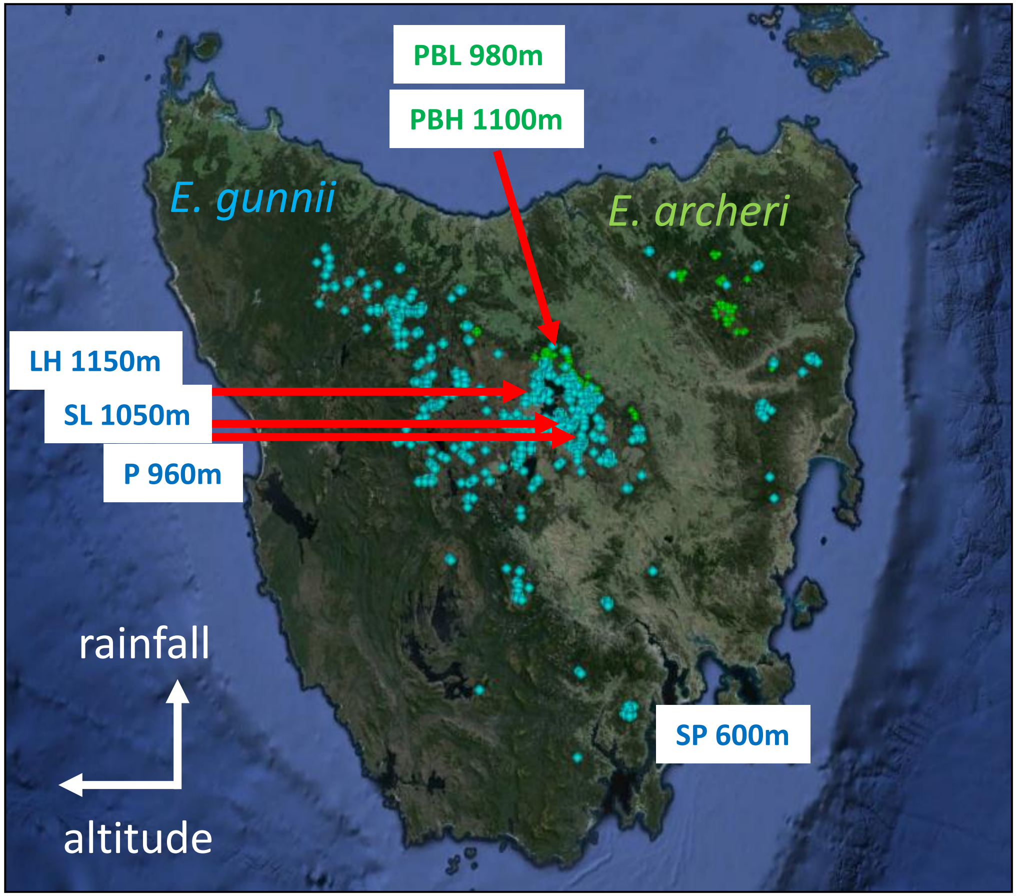
Genetic resistance to *Teratosphaeria* leaf disease increases in home-sites with high disease risk (i.e. high temperatures and high autumn rainfall)

Climate adaptation is likely a genome-wide phenomenon

As sedentary, dominant terrestrial organisms, trees are likely to be strongly coupled, and exposed, to changes in the macro-climate

2. Climate change is impacting native gene pools and local provenance fitness

Clinal variation in the *E. gunnii-archeri* complex on the Central Plateau, Tasmania



Reciprocal transplant trials established in 1979 within wild populations:

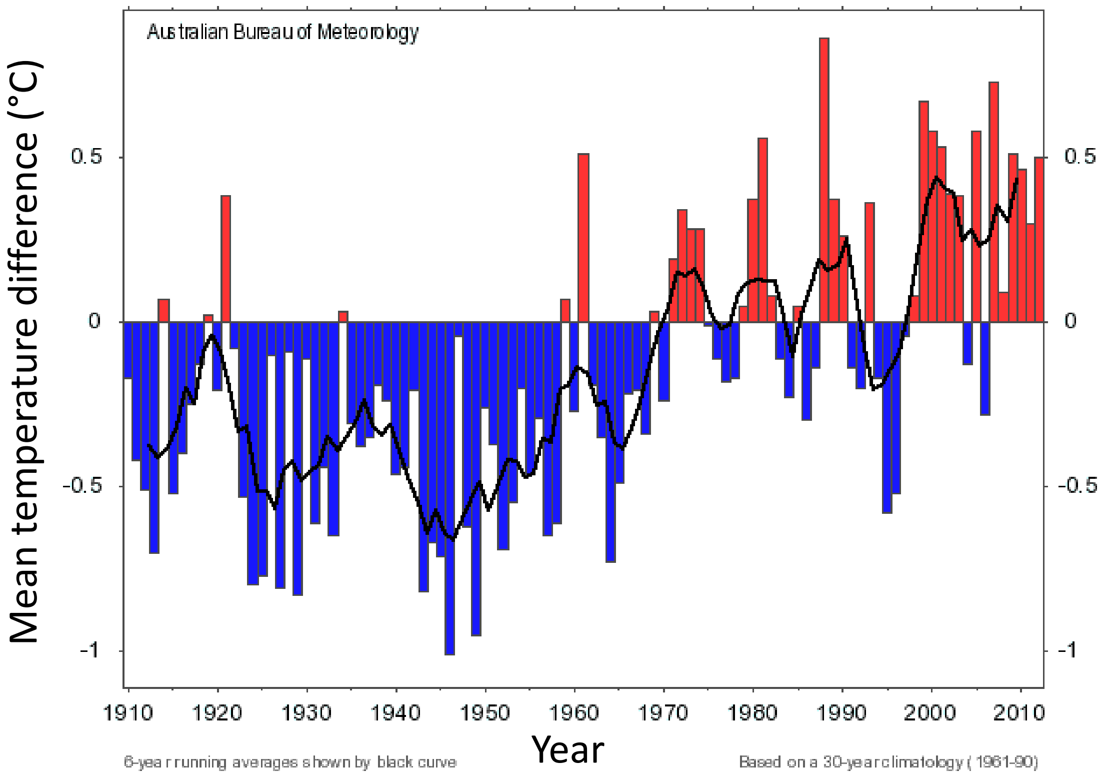
- 4 sites
- 6 provenances
- 12 plants/provenance/site

Potts 1985, Aust J Bot 33: 687-704
Potts et al. 2001, Pap Proc R Soc Tasm 135: 57-61
Calder & Kirkpatrick 2008, Aust J Bot 56: 684-692
Kremer *et al.* 2014, Functional Ecology 28: 22–36

Local climates are changing

Central Plateau region has experienced declining autumn rainfall since 1970's and increasing temperatures

Deviation from long-term mean temperature in Tasmania (1910-2012)

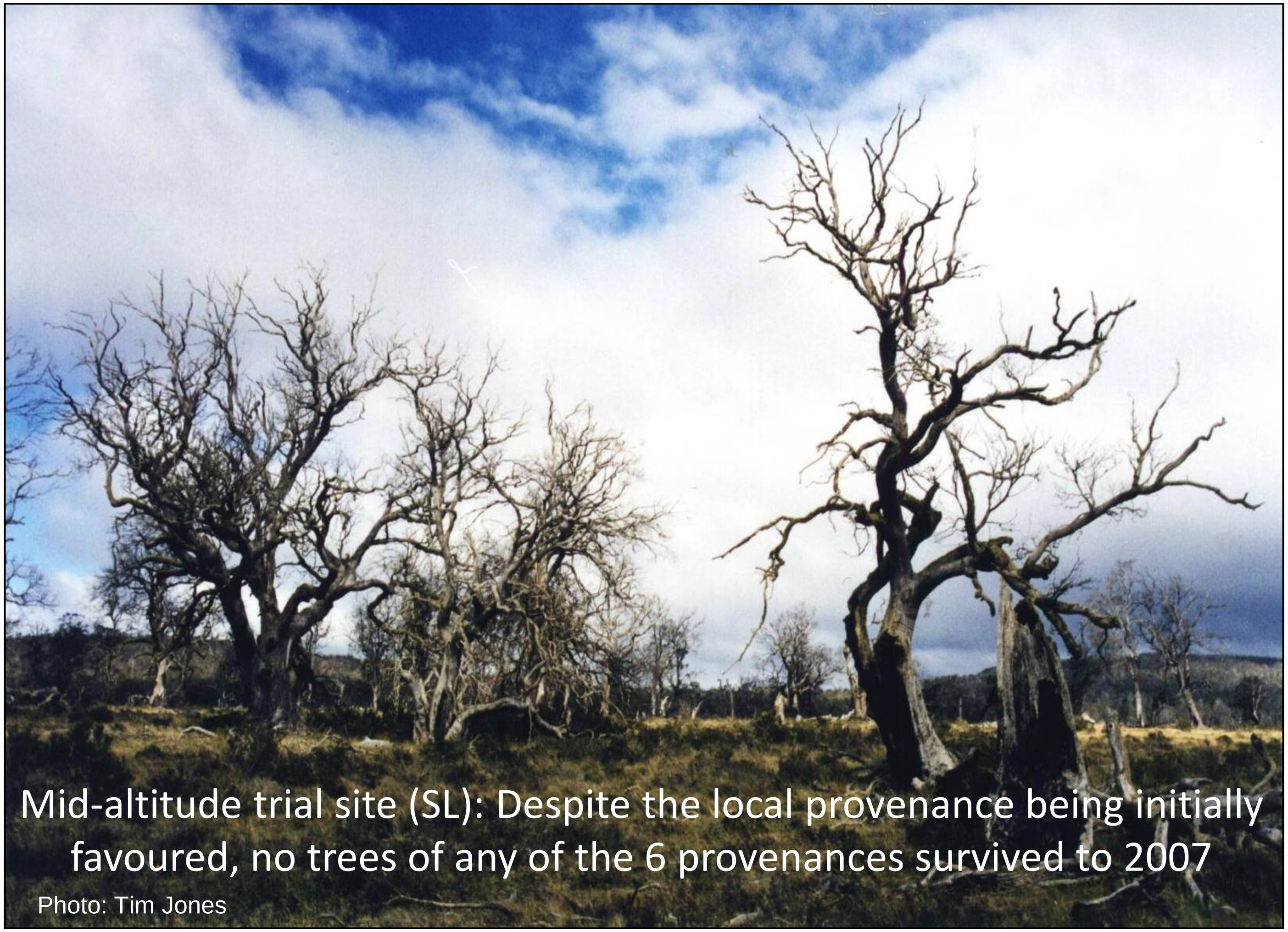


What was once 'locally' adapted may not be 'locally' adapted now or in the future

http://www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=rain&area=tas&season=0112&ave_yr=T

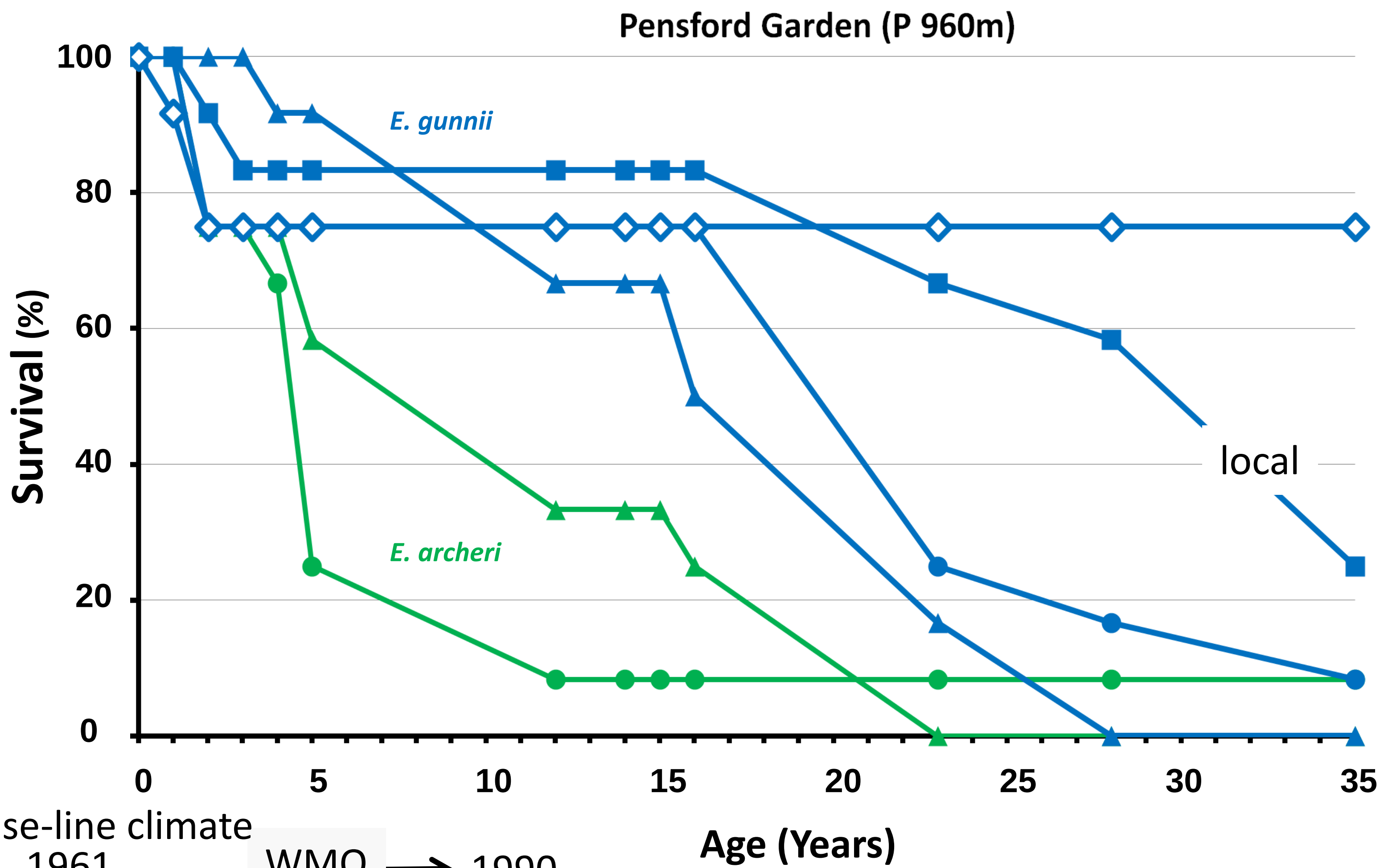
…and eucalypt populations are affected

Major adult tree decline commenced in the early 1990's



Potts et al. 2001, Pap Proc R Soc Tasm 135: 57-61 Calder & Kirkpatrick 2008, Aust J Bot 56: 684-692

Local provenance no longer best at the benign low altitude site



Base-line climate

1961 —— WMO → 1990

1950 —— Worldclim → 2000

—— **Local 960m provenance best** →

—— **Non-local 600m provenance best** →

3. What are we doing?

Testing provenance strategies for revegetation

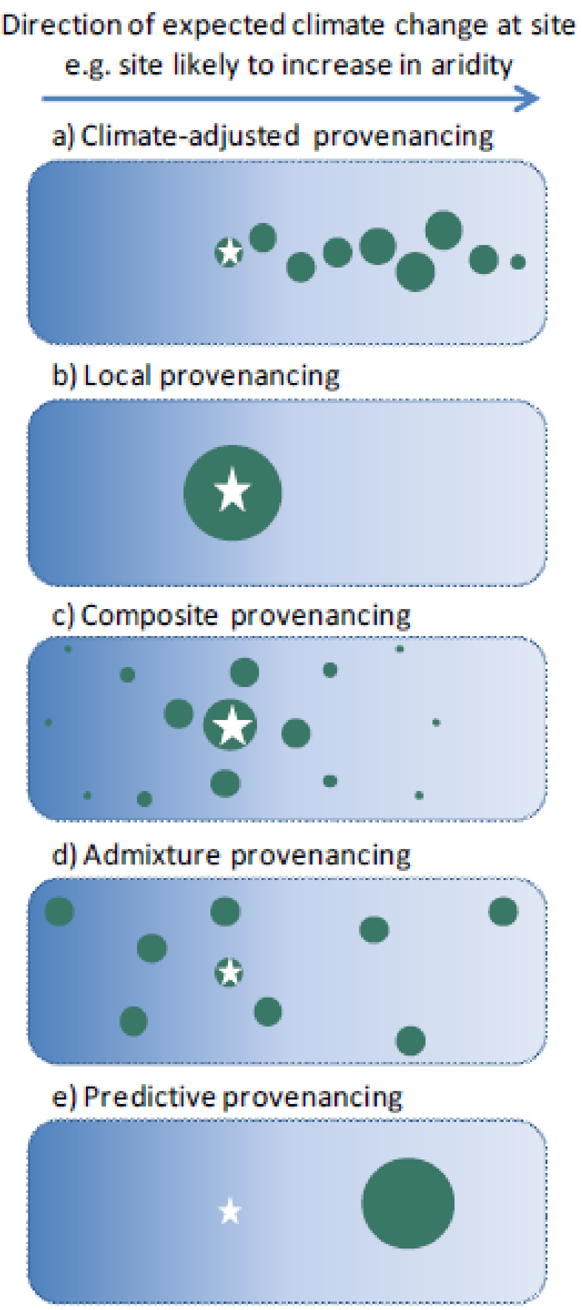
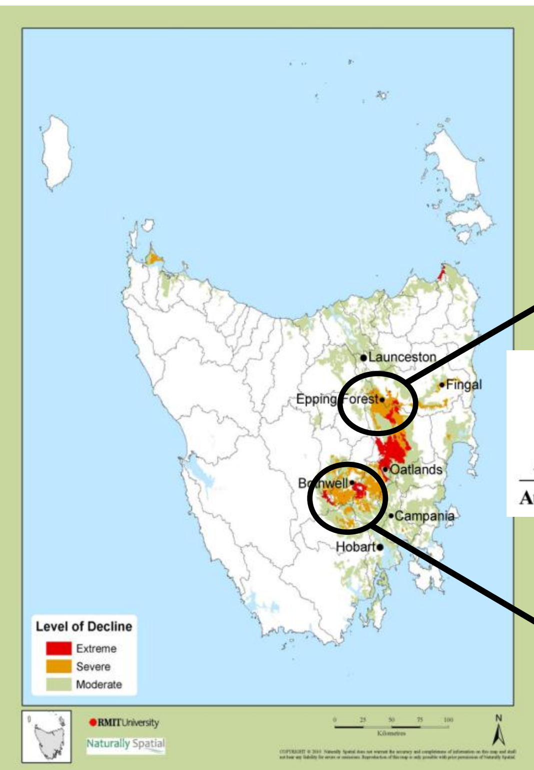


Figure from Prober *et al.* 2015. *Frontiers in Ecology and Evolution* (doi: 10.3389/fevo.2015.00065)

Building a long-term research infra-structure within GA's restoration plantings in Tasmania

c. 20% of restoration plantings are pedigreed local, multi-provenance and multi-species trials

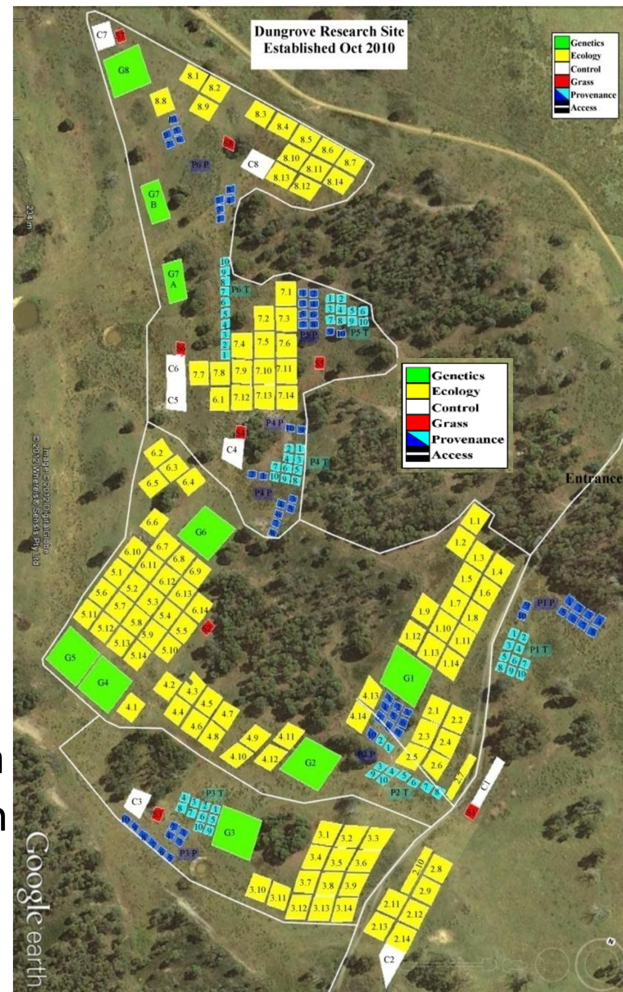
Connorville est. 2014



Two c. 20 ha trial sites in 2014

Australian Government
Australian Research Council

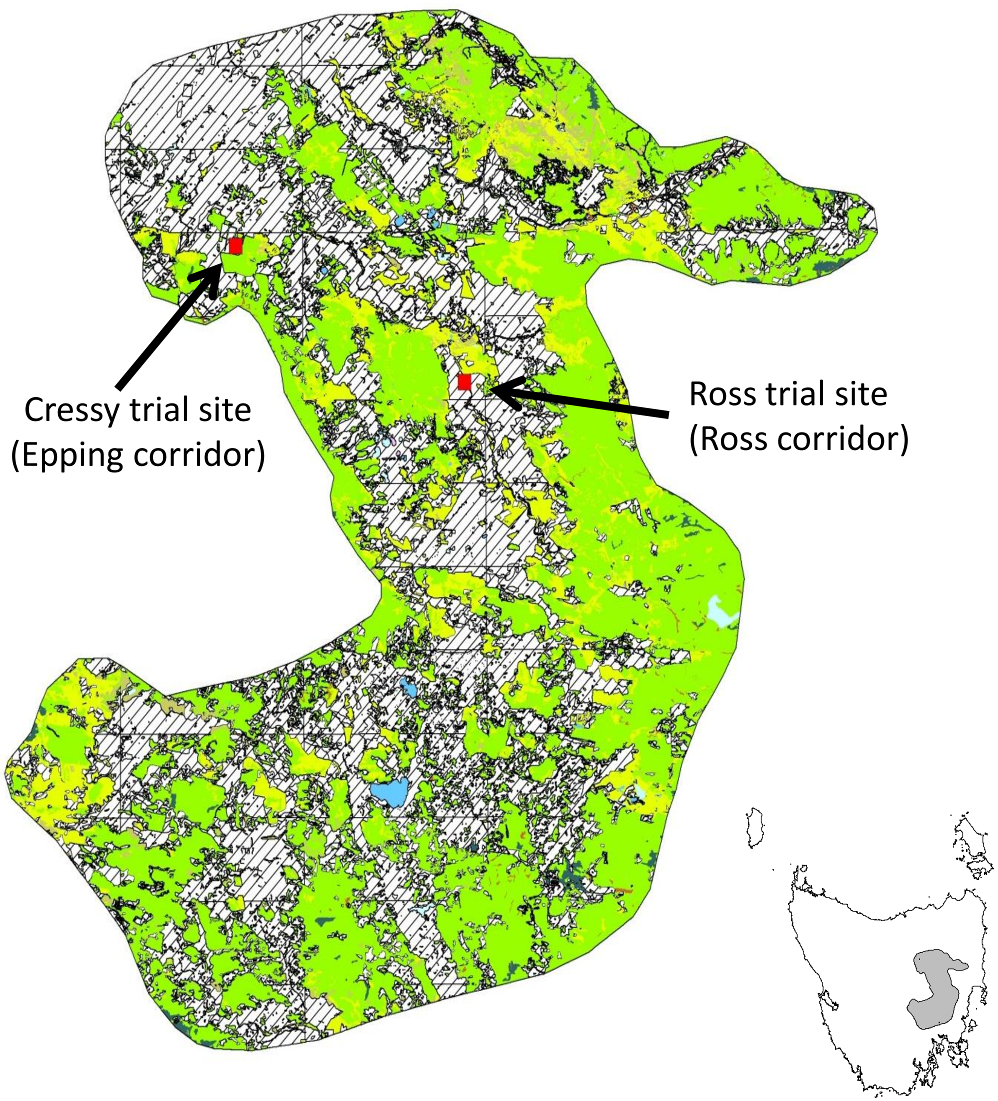
Three 30 ha trial sites in 2010-11



Dungrove est. 2010

Bailey *et al.* 2013, 2015
Gauli 2014

The Midlandscapes project



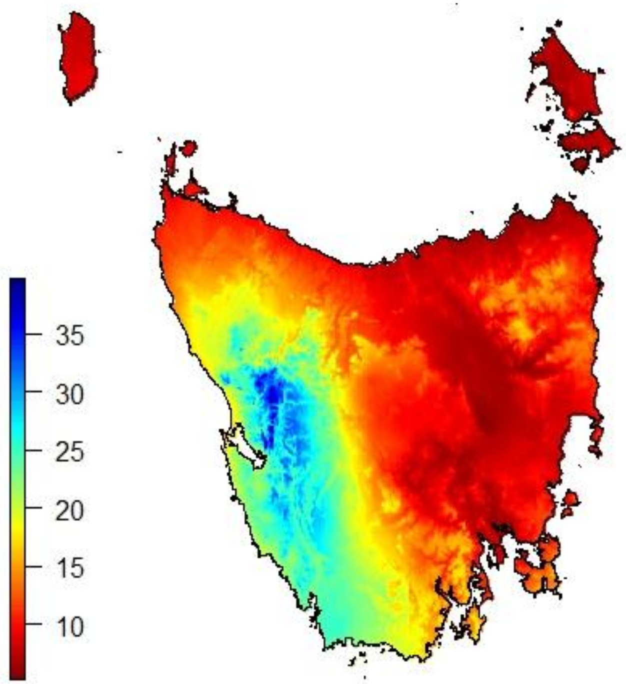
Consortium of stakeholders including GA, TLC, Bush Heritage, DPIPWE and UTAS

Midlandscape encompasses the Midlands Biodiversity Hotspot defined as the lowland plains and foothills between the Eastern Tiers and Western Tiers

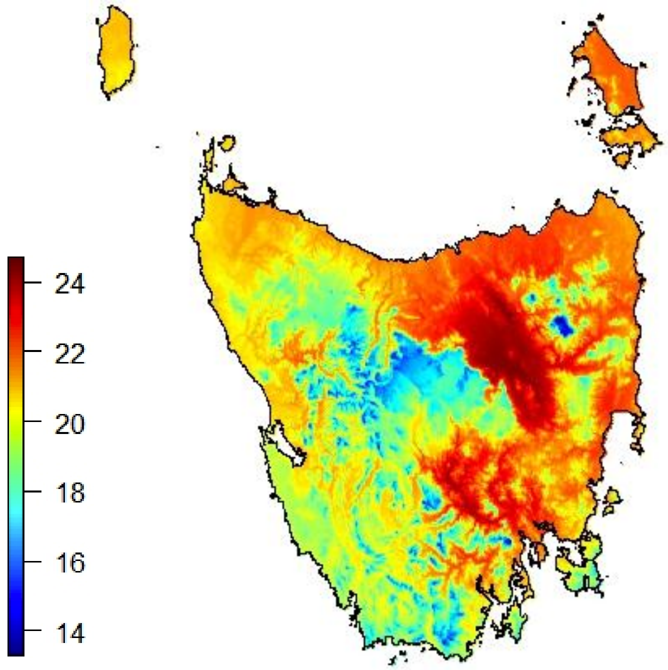
Area of active research and habitat restoration projects

A challenging climate – hot & dry (by Tasmanian standards)

- Lowest rainfall within the state
- Epicenter of high temperature extremes



Precipitation of the driest month (mm)

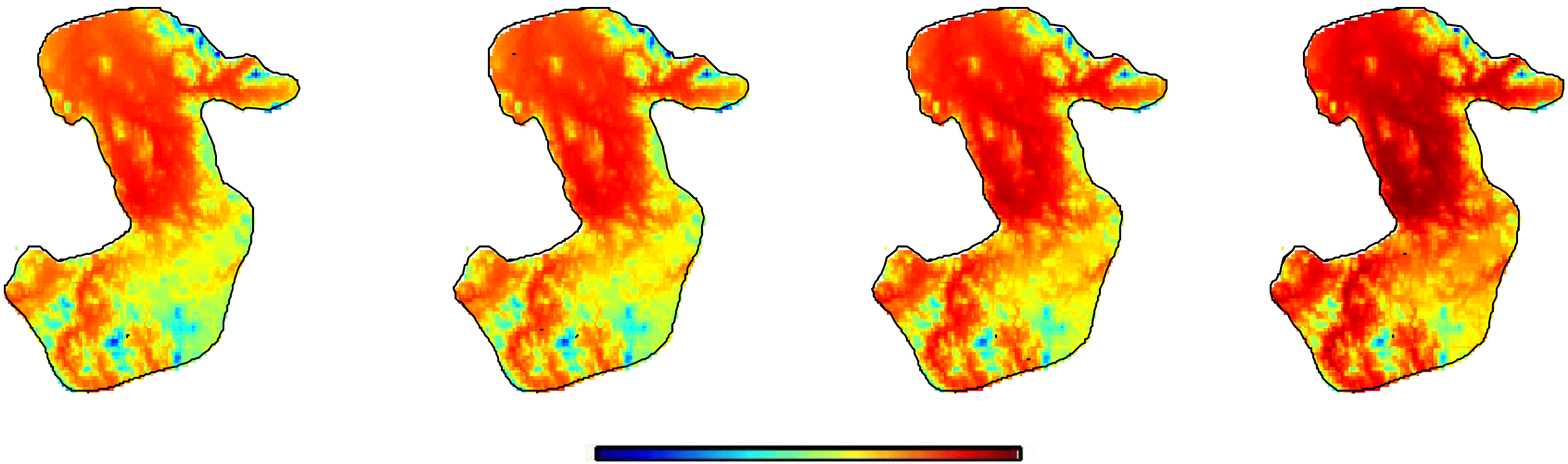


Maximum temperature of the warmest month (°C)

Will get worse

Midlandscape predicted to become more arid during summer in the future

1960-1990 | 2020 | 2050 | 2080

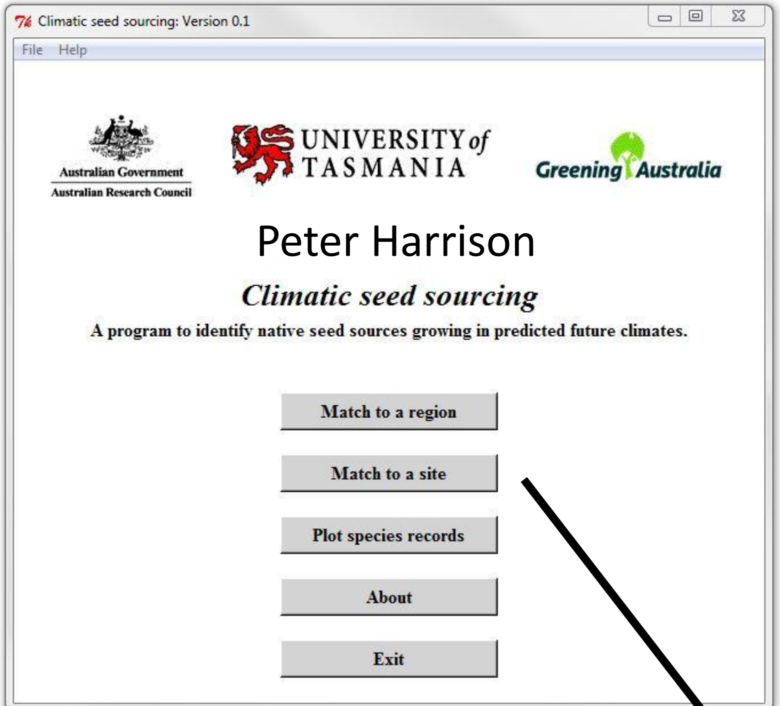


Wet and cold

Dry and hot

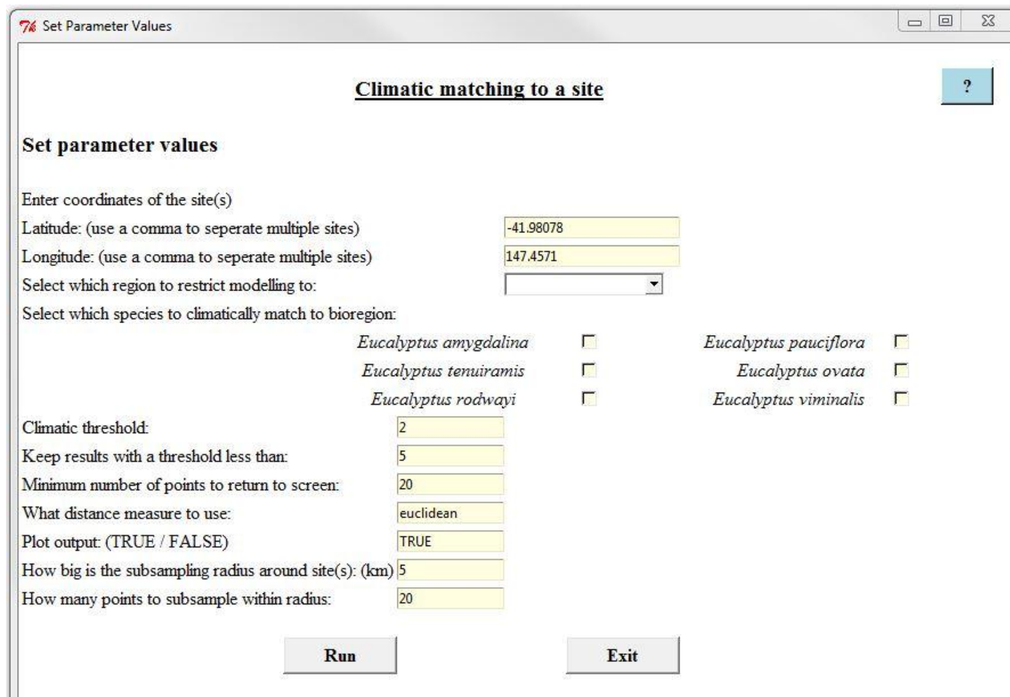
+ 2.6 °C increase in maximum temperature of the warmest month

Seed sourcing for future climates – the program



Options of the program

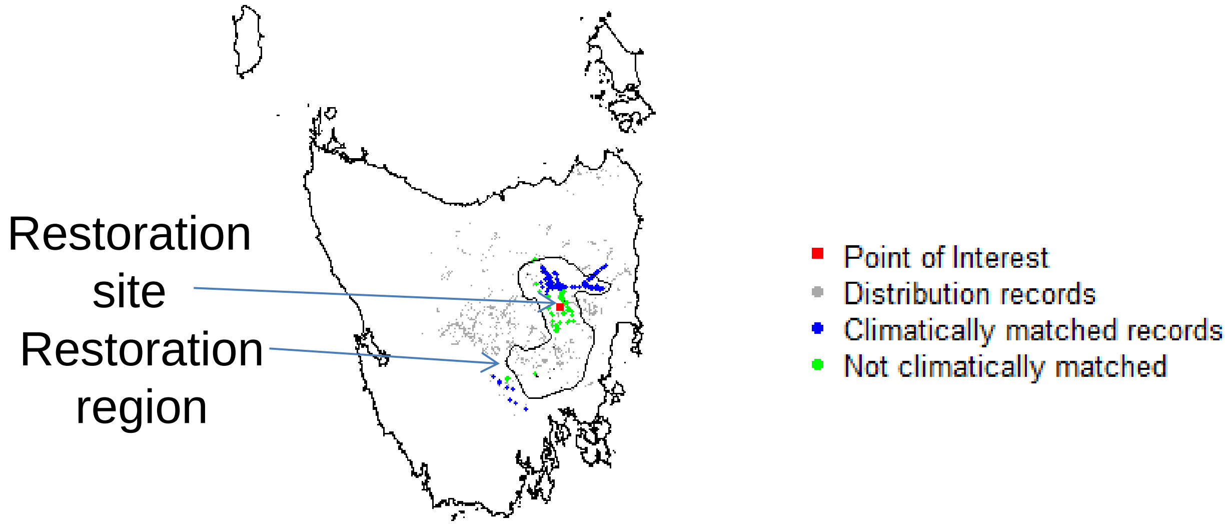
Climate-match a species to a region
<u>Climate-match a species to a site</u>



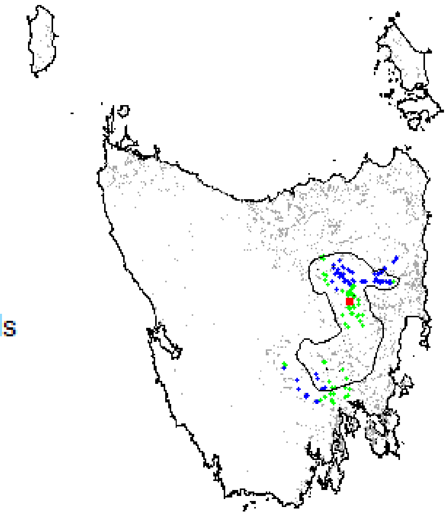
Set multiple parameters for the model and select the species you want to match

Seed sourcing for future climates – the output

E. pauciflora (2050s)



E. ovata (2050s)



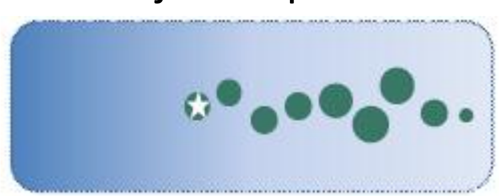
pauciflora_1_2050

lon	lat	collect	ClimDist	GeoDist	location	frag
147.75	-41.757	1	0.94591	34.94	Avoca	1
147.8	-41.739	1	0.97314	39.28	Fingal	0
147.79	-41.746	1	0.98688	37.78	Fingal	1
147.79	-41.742	1	0.98688	38.2	Fingal	1
147.77	-41.752	1	1.04518	36.07	Avoca	1

ovata_1_2050

lon	lat	collect	ClimDist	GeoDist	location	frag
146.87	-42.687	1	0.82255	92.29	Glenora	1
146.87	-42.689	1	0.82255	92.4	Glenora	1
147.75	-41.757	1	0.94591	34.94	Avoca	1
147.8	-41.739	1	0.97314	39.28	Fingal	0
147.79	-41.746	1	0.98688	37.78	Fingal	1

Climate-adjusted provenancing



Field testing seed sourcing strategies

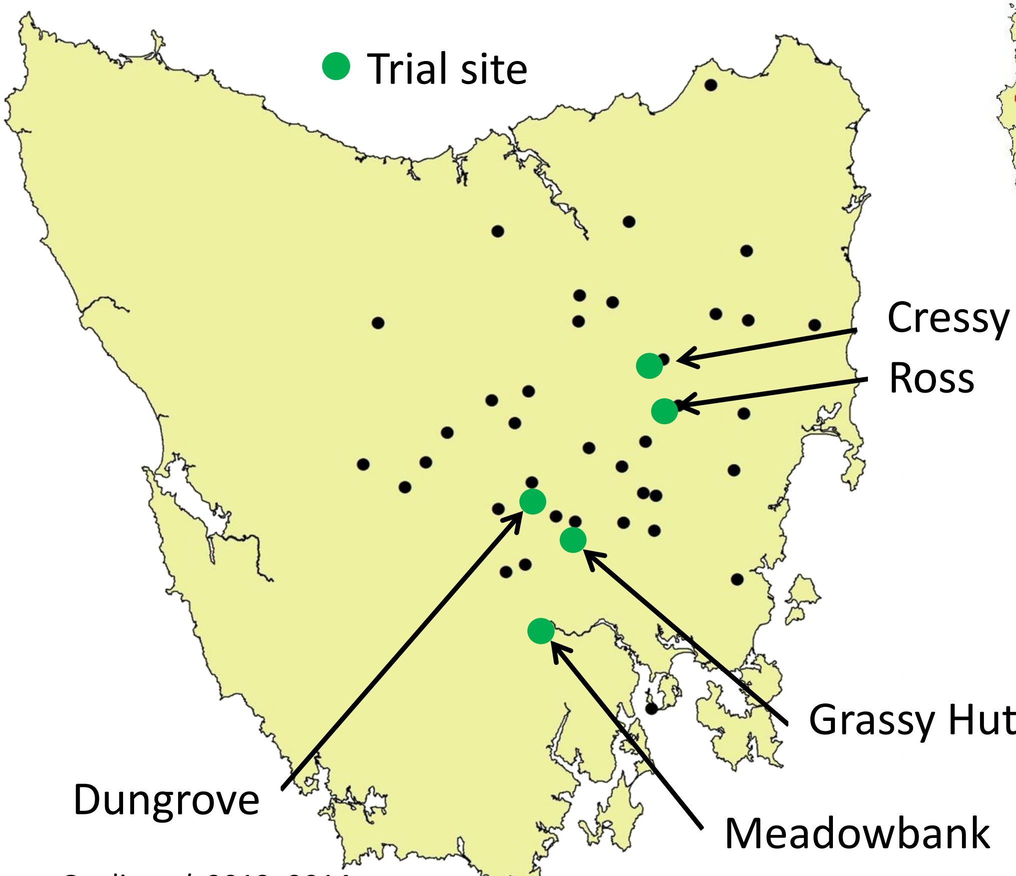
Seed collection localities in Tasmania (local + non local)

Eucalyptus pauciflora [•]

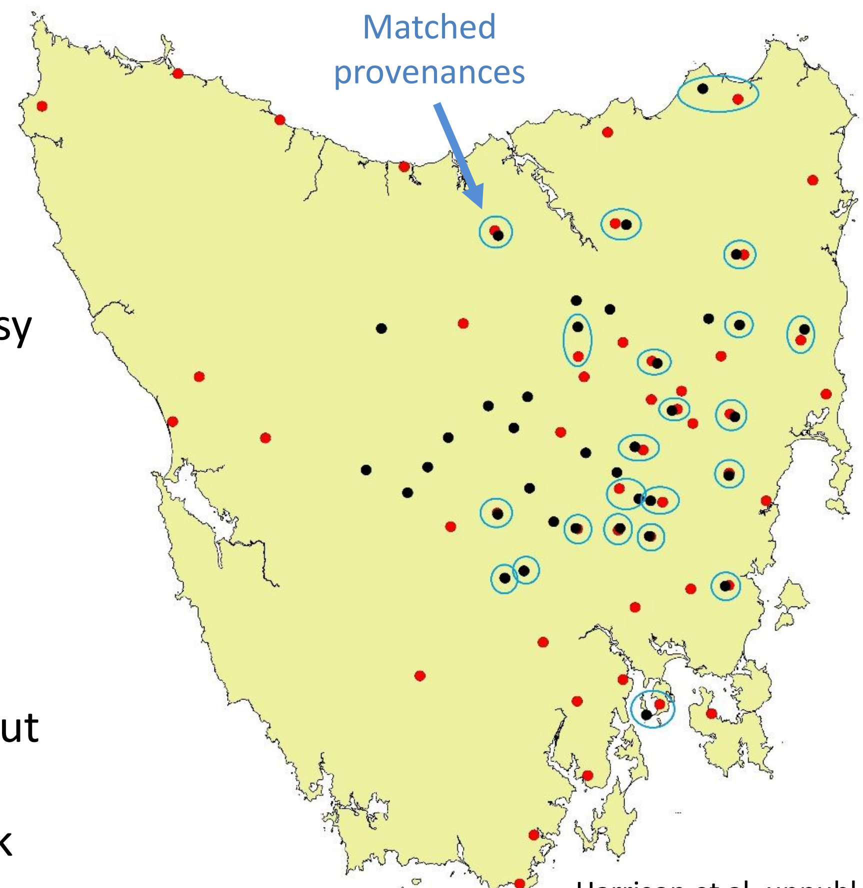
280 Tasmanian trees (families)
37 Tasmanian provenances
13 Mainland provenances

Eucalyptus ovata [•]

400 Tasmanian trees (families)
51 Tasmanian provenances
(22 paired with *E. pauciflora*)



Gauli *et al.* 2013, 2014

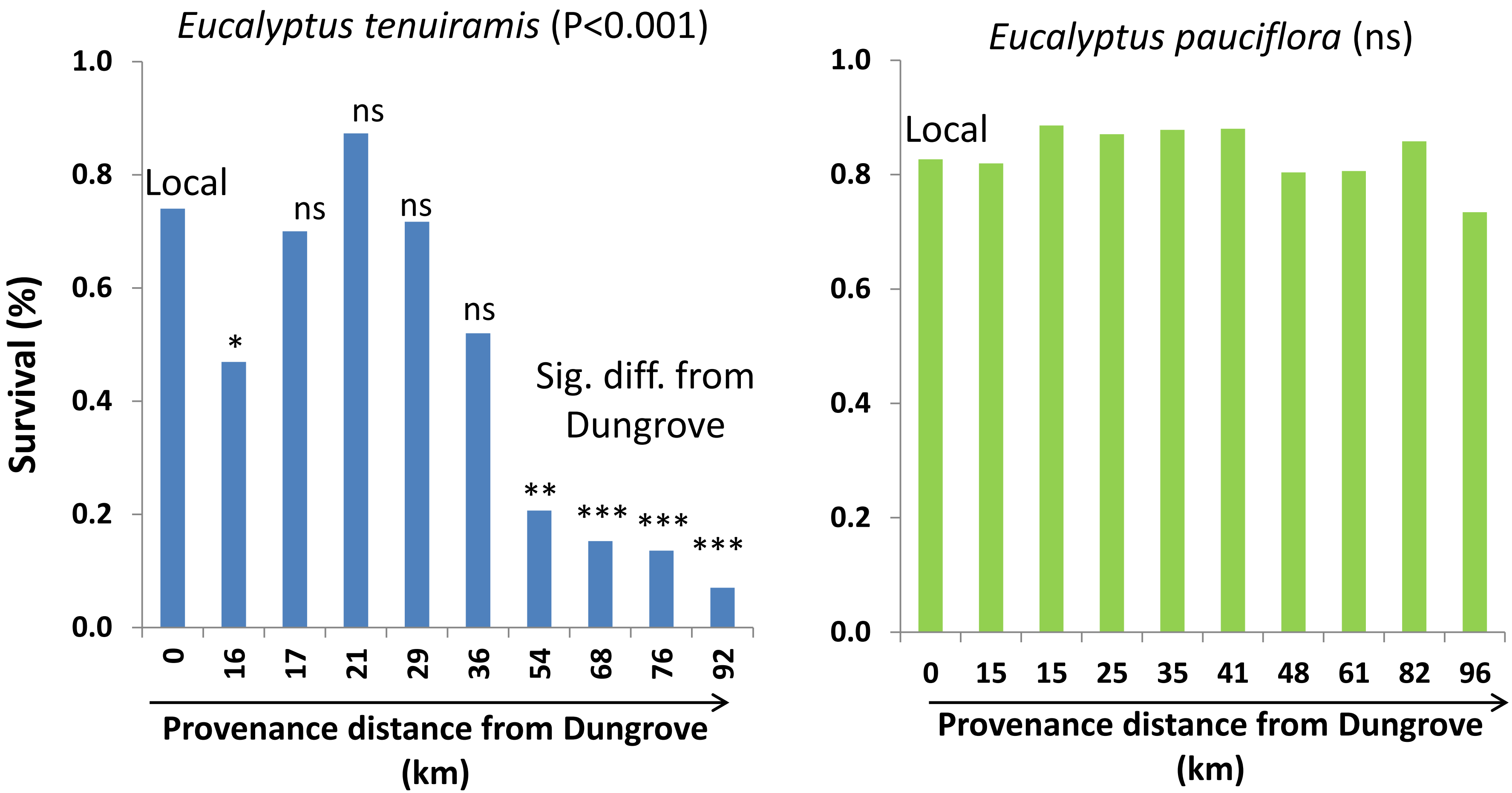


Harrison et al. unpubl.

Climate change thresholds may be species-specific

Dungrove provenance trial

3 year suvival in blocks of 25 trees from 10 provenances replicated 8 times



Bailey *et al.* unpubl. data

4. There may be ways to short-cut field testing

MOLECULAR ECOLOGY

Molecular Ecology (2014) 23, 2500–2513 doi: 10.1111/mec.12751

Genome-wide scans detect adaptation to aridity in a widespread forest tree species

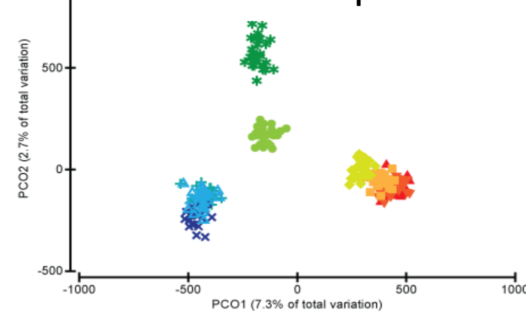
DOROTHY A. STEANE,*†[1] BRAD M. POTTS,*[1] ELIZABETH MCLEAN,‡ SUZANNE M. PROBER,§ WILLIAM D. STOCK,¶ RENÉ E. VAILLANCOURT* and MARGARET BYRNE‡

Genomic approaches to identify climatic drivers of adaptive variation

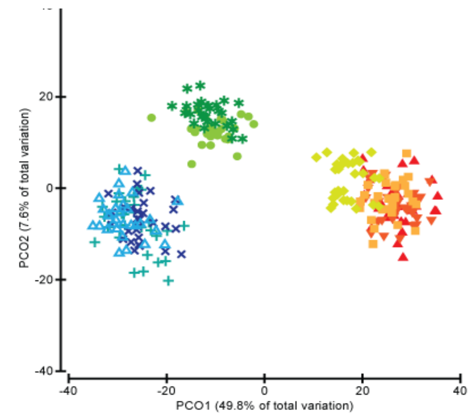
The case of *E. tricarpa*

A combination of climate variables 'aridity index' maximally correlated with genome-wide changes in markers showing signatures of disruptive selection

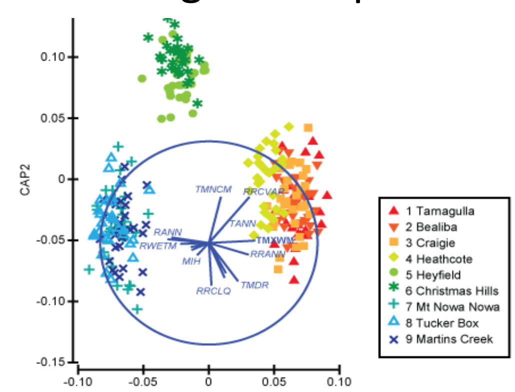
Genetic space



Adaptively enriched genetic space



Climatically aligned adaptive genetic space

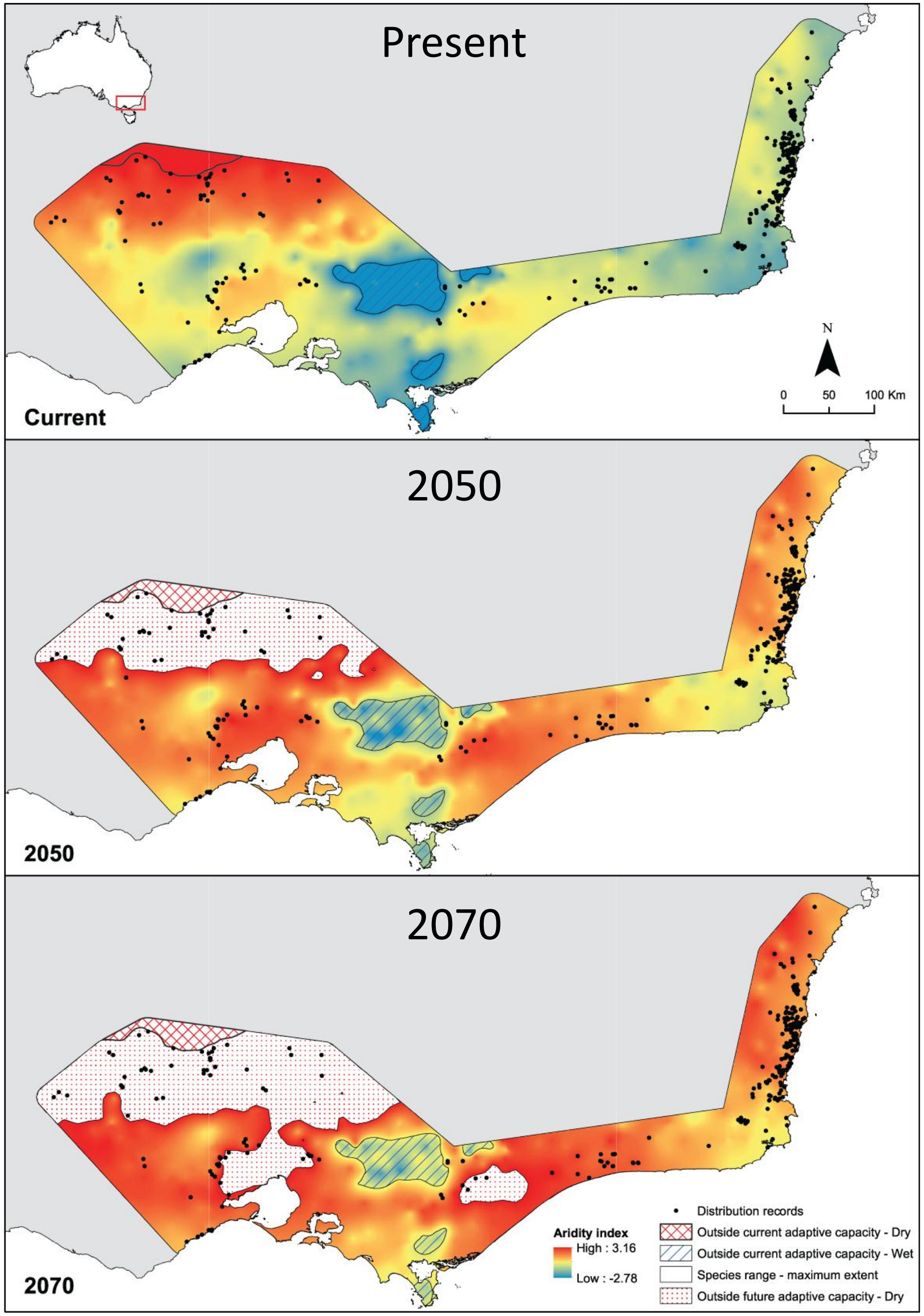


Predicting adaptive surfaces for contemporary and future climates

Weighting climatic variables and their change according to likely selective impact

Can local populations adapt from the standing genetic variation and natural gene flow?

Harrison *et al.* unpubl data



CSIRO global climate model for 2050 and 2070

5. A wildcard: exotic pests and diseases

Exotic pests and diseases may impact the ecological and evolutionary trajectory of revegetation?

Feral fallow deer (*Dama dama*)

Deer damage at Dungrove was significantly greater on the faster growing, low altitude *E. pauciflora* provenances (Gauli 2014; Bailey *et al.* 2015)

Thank you

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