



Provenance issues in a Changing World

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NATIONAL RESEARCH COLLECTIONS AUSTRALIA/CANBR
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Provenance

- Not a new concept
  - Early 19th Century (forest) scientists
  - Common garden experiments
  - Especially important forestry tool

- What do we think it means?
  - Populations exhibit localised adaptation
    - Environmental conditions
    - Disease & pathogens
    - Herbivores
    - Pollinators

Images from Nambiar and Brown (eds) 1997

Why might provenance be important?

- Influences two major seed sourcing concerns

1. Capturing adaptive evolutionary potential (i.e. genetic diversity) – changing environments

2. Geographic scale over which seed can be moved
    - Maladaptation (can't survive new conditions)
    - Outbreeding depression (poor offspring produced by divergent genomes)
    - Superior fitness (weediness)
    - Inappropriate timing – flowering, seed (pollinator time lag)

Provenance & local adaptation

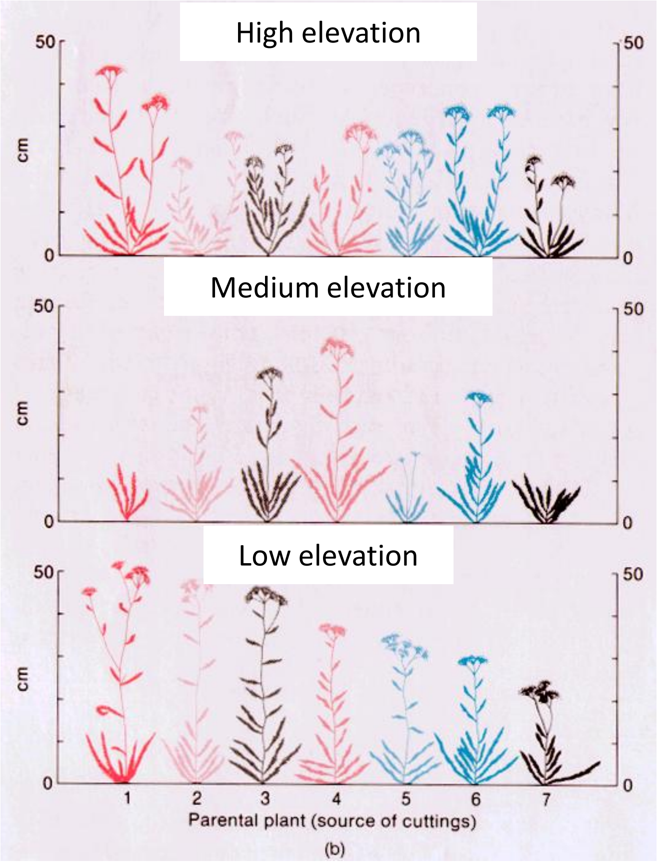
- Long-standing precautionary principle
  - Local plants do better that non-local since they are adapted to local environment
  - Theory predicts further apart populations are, less likely non-local plants will survive
- 5, 10, even 100 km considered "local" but some evidence for adaptation over very small scales (25 m)
- Provenance linked to
  - Environment
  - Life history (longevity, breeding system, pollinator & soil interactions)
  - Geographic distribution
  - Genetics

Provenance & local adaptation

- Difficult to detect– need to do transplant experiments (time-consuming, expensive)

Achillea millefolium

- Clones 7 plants at 3 elevations.
- Responses differ depending on clone



Example and image from Griffiths *et al*. (1993)

Australian evidence for local adpatation

- Hancock et al. (2013)
  - Six species – *Acacia falcata, Bursaria spinosa ssp. spinosa, Eucalyptus crebra, E. tereticornis, Hardenbergia violacea and Themeda australis*
  - Multiple provenances planted in two field sites
  - Little evidence of local superiority germination and initial growth apart *B. spinosa* and some traits *T. australis*

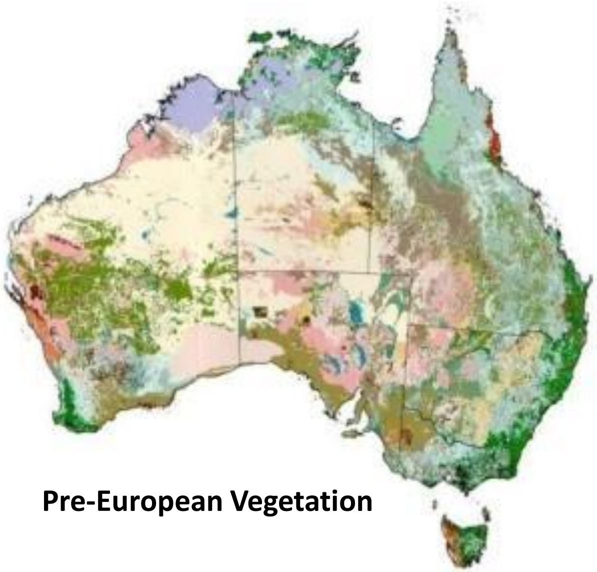
- Hancock et al. (2014)
  - *Eucalyptus tereticornis and Themeda australis*
  - 2050 climate conditions
  - No evidence local superiority
  - Some evidence increased herbivory on local *E. tereticornis* seed under ambient conditions

Australian evidence for local adaptation

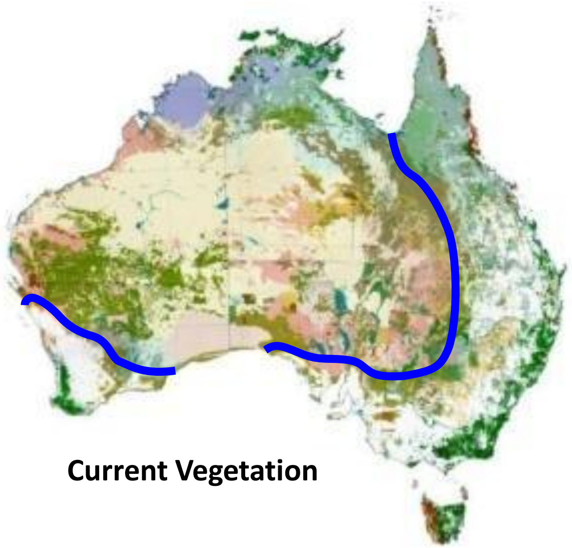
- Pickup et al. (2012)
  - *Rutidosis leptorrhyncoides*
  - 12 population pairs from distances ranging 0.7-600 km
  - Evidence local adaptation varied populations and traits
  - Local populations did better for seedling survival but not biomass
  - Foreign populations did better for number of inflorescences (reproduction)

Changing times for Australia plants

- Substantial changes to vegetation abundance and distribution resulted in
  - Irreversible loss of genetic diversity
  - Small and more isolated populations – changed plant processes



Pre-European Vegetation



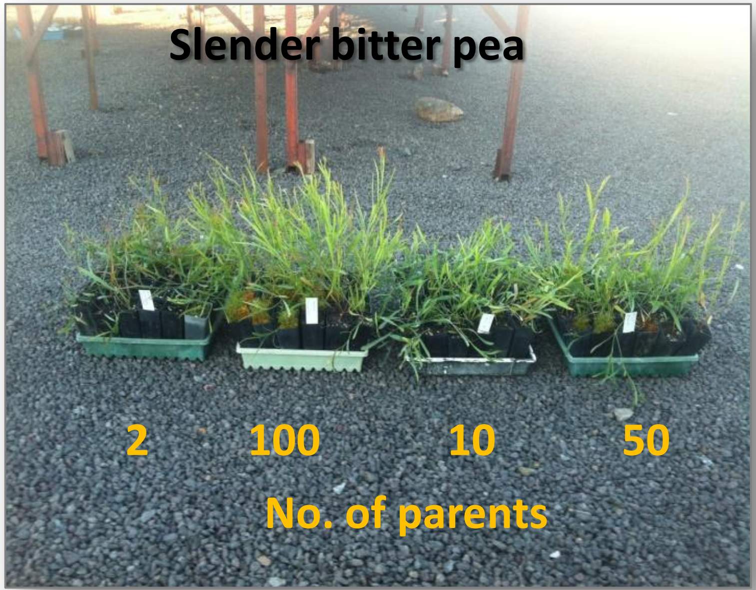
Current Vegetation

Changing times for Australia plants

- Complex challenges for plants (static)
  - Reliant biotic/abiotic vectors pollen and seed dispersal

Changing times for Australia plants

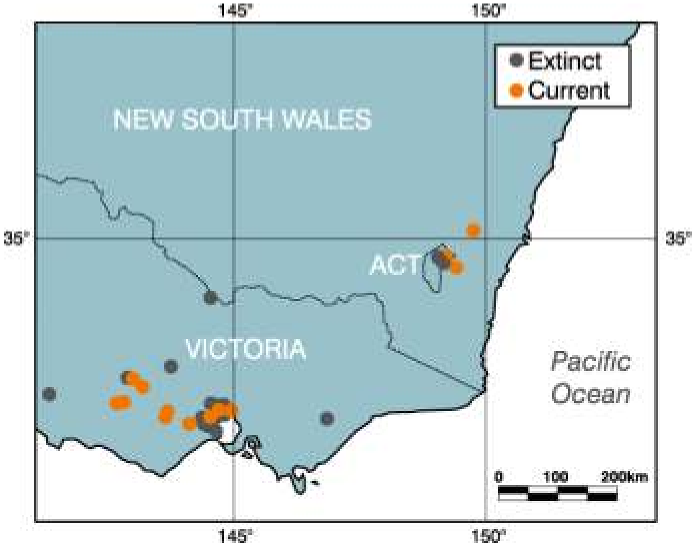
- Influence genetic and demographic processes
  - Elevated inbreeding
  - Impacts seed production and quality



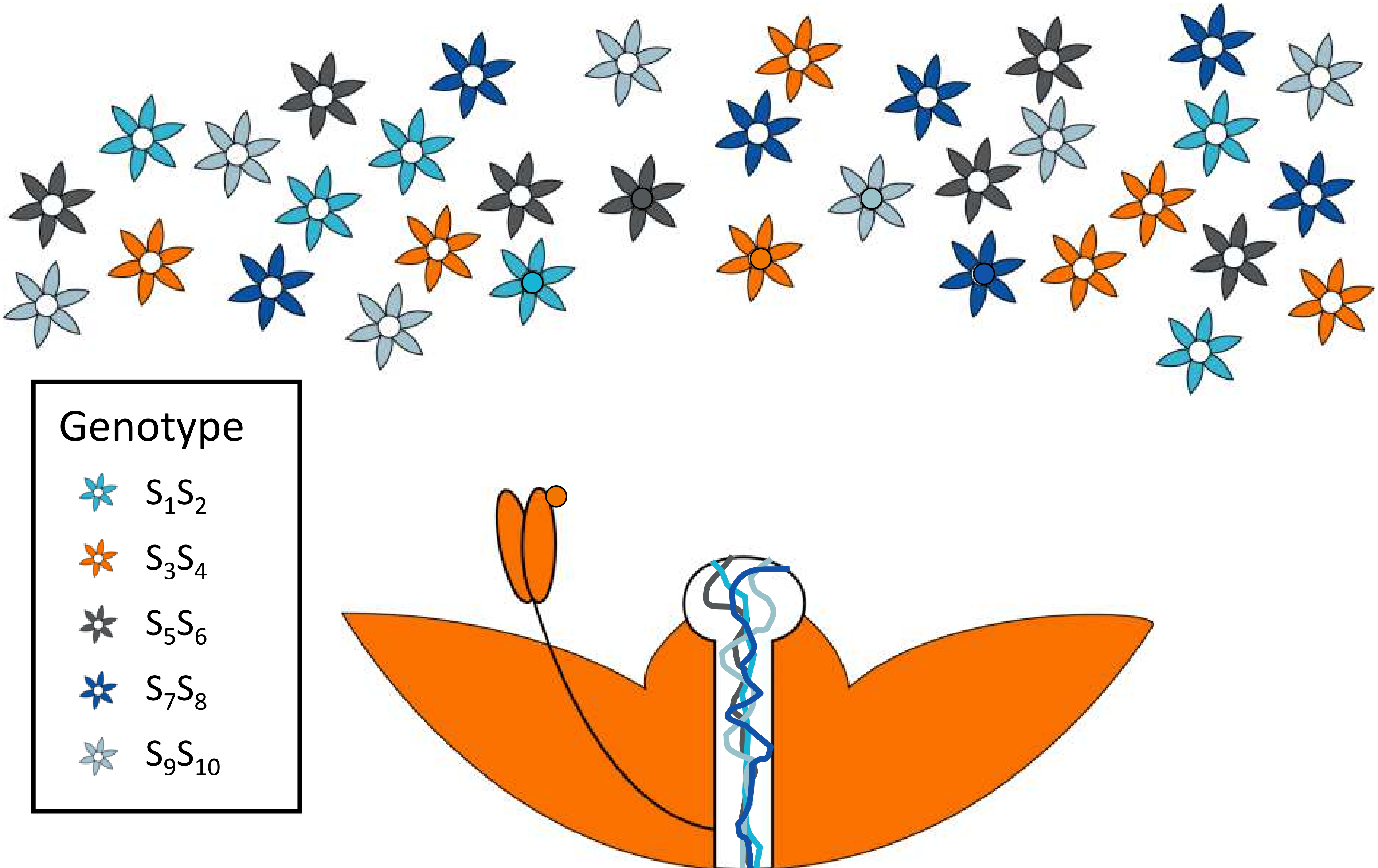
Andie Guerin

Effects of land clearing

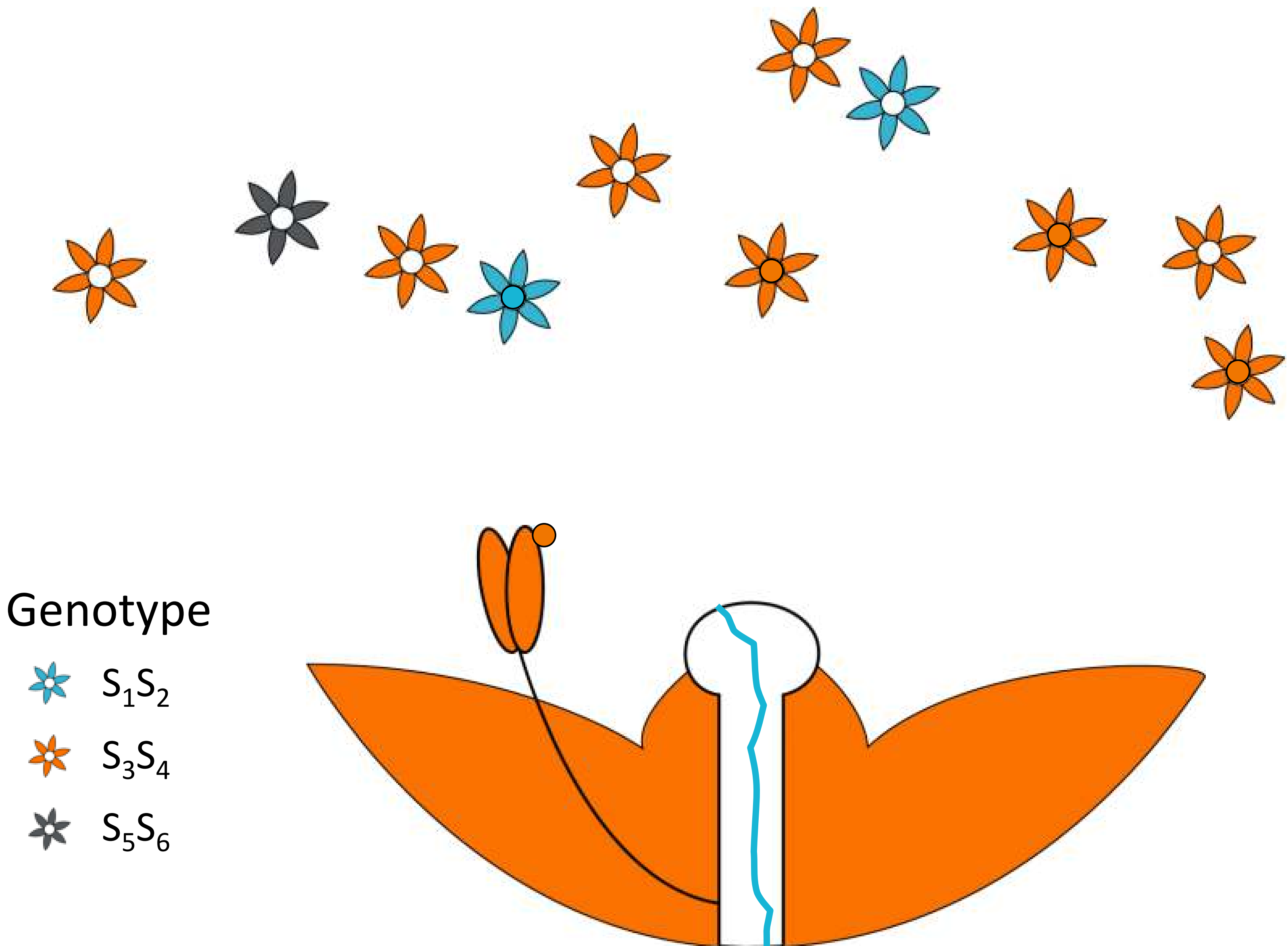
- Button wrinklewort (*Rutidosis leptorrhyncoides*)
  - Herbaceous perennial (understorey/grassland restoration)
  - Lives ~20 years
  - Severe habitat loss
  - Generalist pollinators
  - Self-incompatible
  - Small pops (<200 plants)
    - Low seed set
    - Poor recruitment
    - Population decline



Self-Incompatibility – Large population

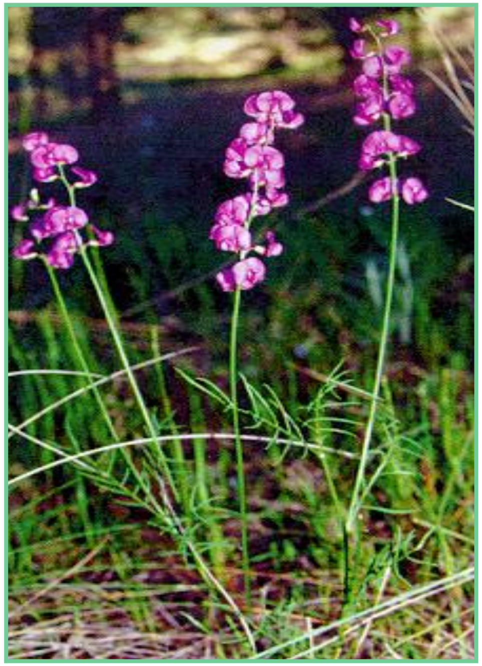


Self-Incompatibility – Small population

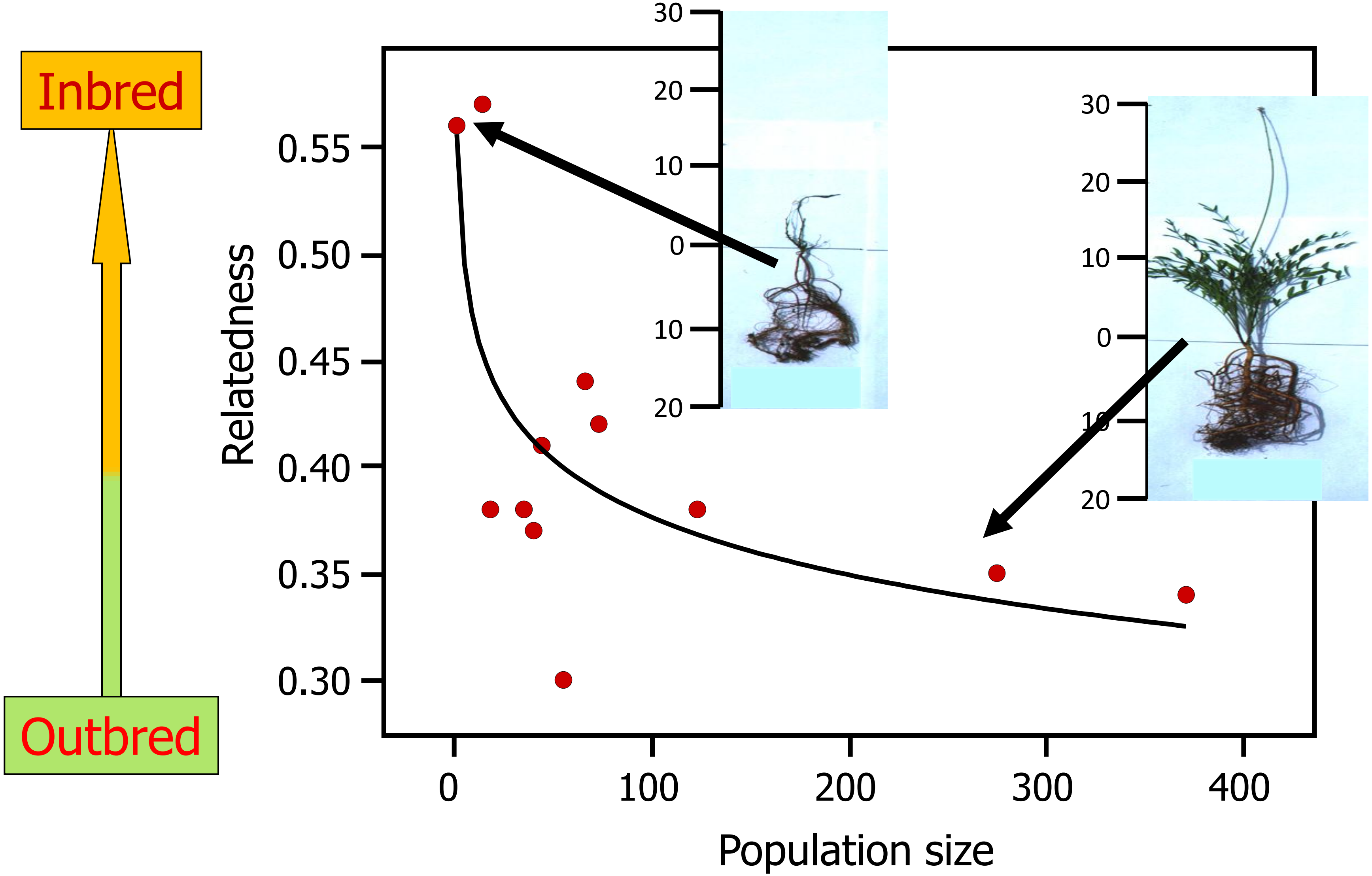


Effects of land clearing

- Mountain Swainson-pea (*Swainsona recta*)
  - Herbaceous perennial (understorey/grassland restoration)
  - Lives ~ 20 years
  - Severe habitat loss
  - Insect pollinators
  - Self-compatible
  - Small pops (10-400 plants)
    - Seed set maintained in small populations
    - Poor recruitment
    - Population decline



Inbreeding effects - *Swainsona recta*



Summary

Small outcrossing populations – low seed set, low genetic diversity

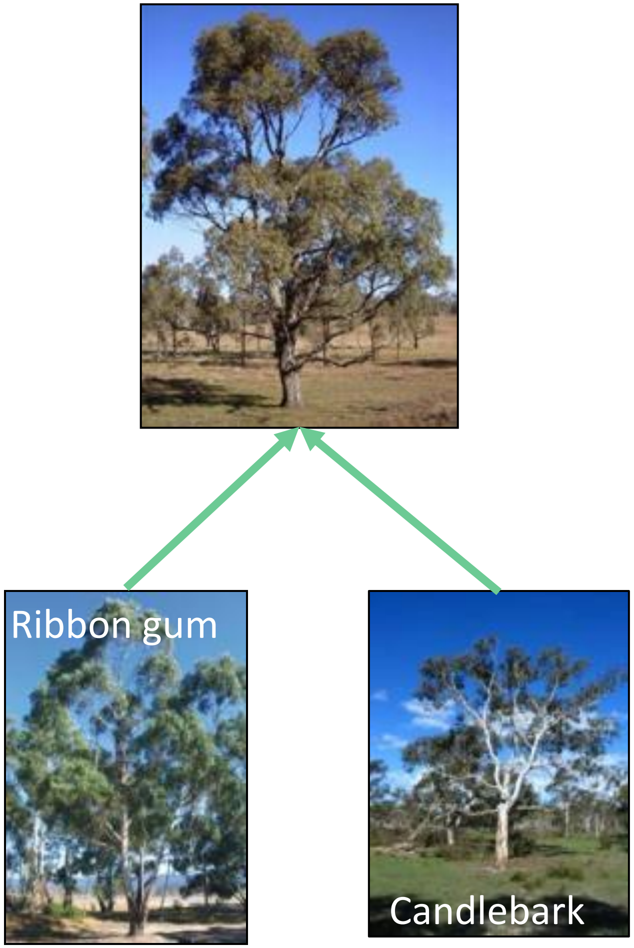
Small selfing populations – poor quality seed, low genetic diversity

Poor for restoration

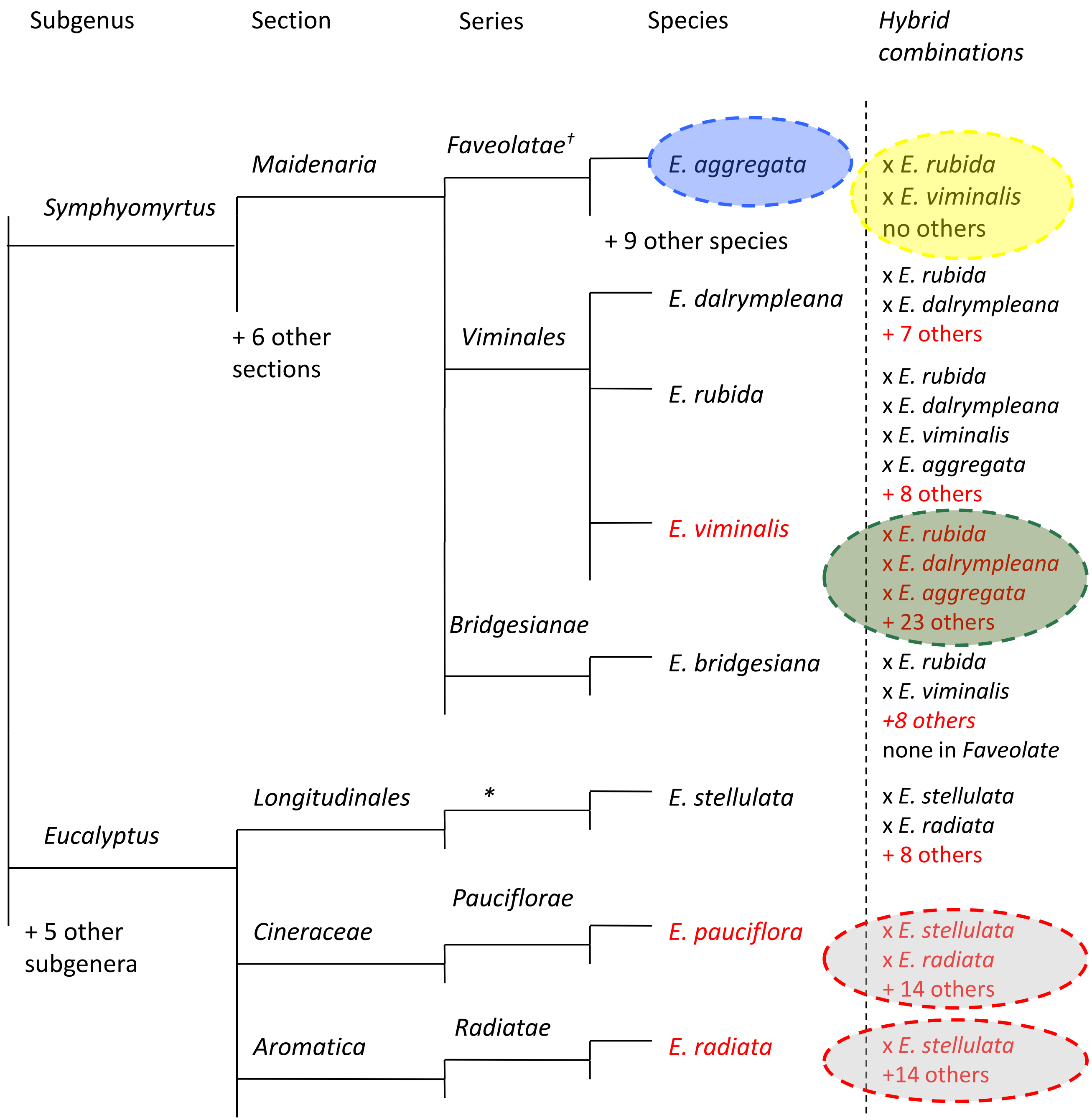
Name	Reproduction
Grevilleas	Slightly-highly self-compatible
Banksias	Self-compatible to self-incompatible
Acacias	Self-incompatible (?)
Eucalypts	Mixed
Daisies	Self-incompatible

Effects of land clearing

- Black gum (*Eucalyptus aggregata*)
  - Woodland tree SE tablelands
  - Insect pollinated mixed mating
  - Highly herbivore resistant
- Known to hybridise with *E. viminalis* and *E. rubida*
- Seedlings from degraded sites have unusual morphology



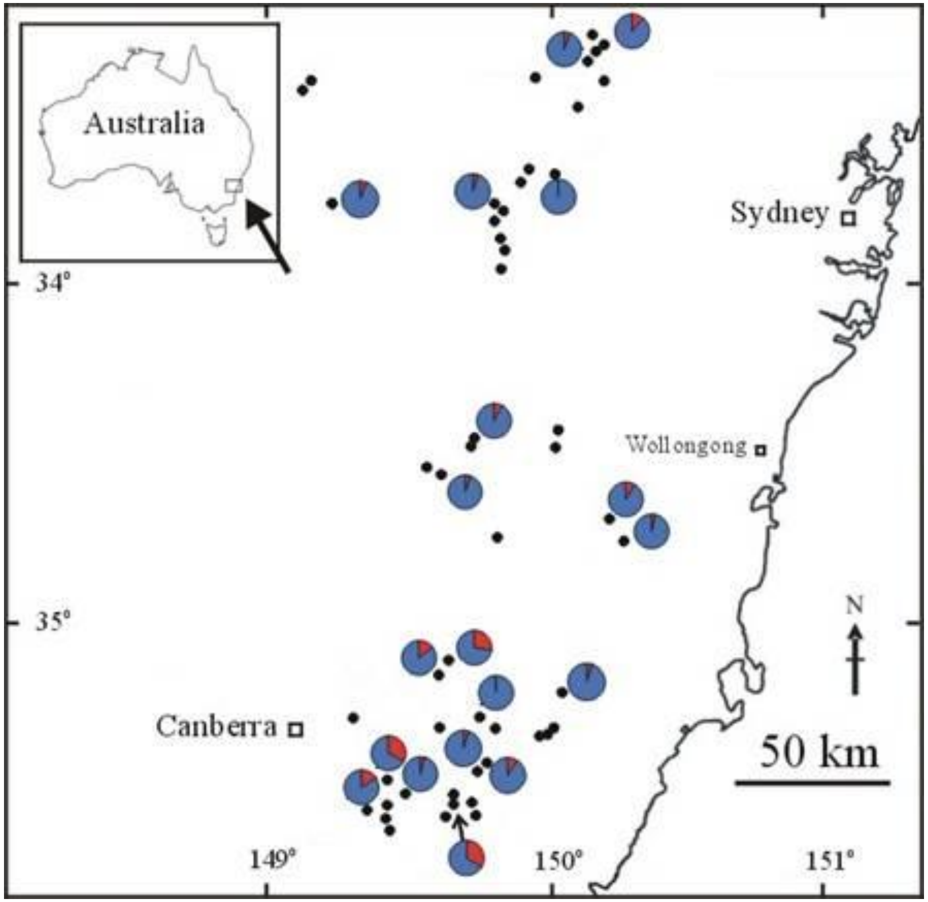
E. viminalis　　*E. rubida*



Subgenus
Section
Series
Species
Hybrid combinations
Symphyomyrtus
Maidenaria
Faveolatae†
E. aggregata
x E. rubida
x E. viminalis
no others
+ 9 other species
+ 6 other sections
Viminales
E. dalrympleana
x E. rubida
x E. dalrympleana
+ 7 others
E. rubida
x E. rubida
x E. dalrympleana
x E. viminalis
x E. aggregata
+ 8 others
E. viminalis
x E. rubida
x E. dalrympleana
x E. aggregata
+ 23 others
Bridgesianae
E. bridgesiana
x E. rubida
x E. viminalis
+8 others
none in Faveolate
Eucalyptus
Longitudinales
*
E. stellulata
x E. stellulata
x E. radiata
+ 8 others
+ 5 other subgenera
Cineraceae
Pauciflorae
E. pauciflora
x E. stellulata
x E. radiata
+ 14 others
Aromatica
Radiatae
E. radiata
x E. stellulata
+14 others

Hybridisation rates

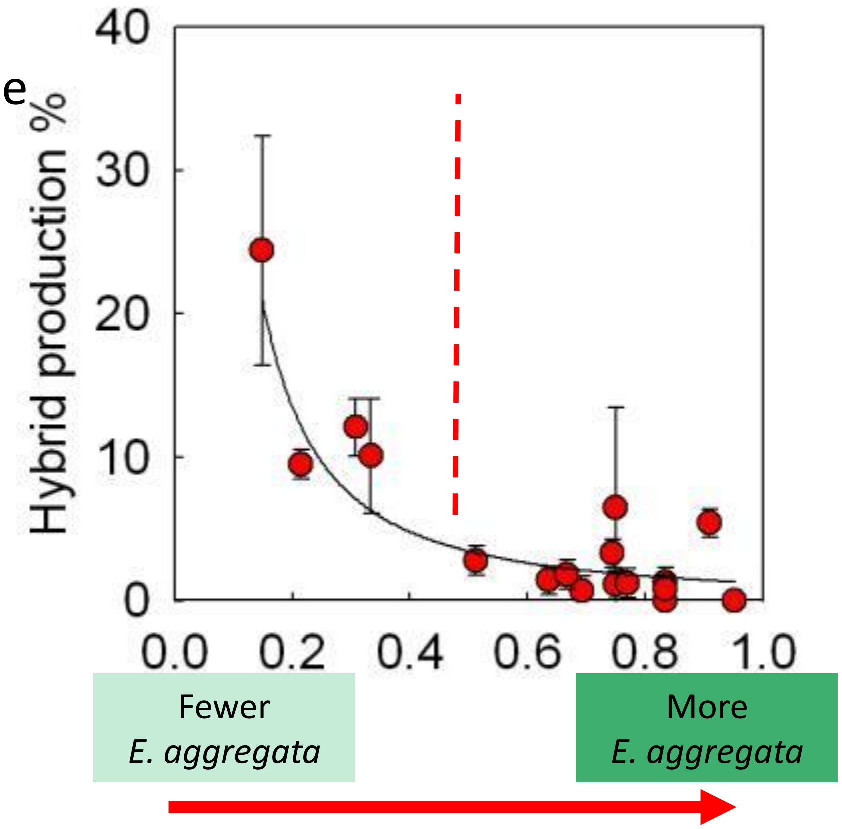
- Genetic assessment
  - 2800 seedlings from 130 adults
  - 80% of 19 populations had hybrid seed
  - Average ~9% (high for *Eucalyptus*)
  - Range from 0% to 31%



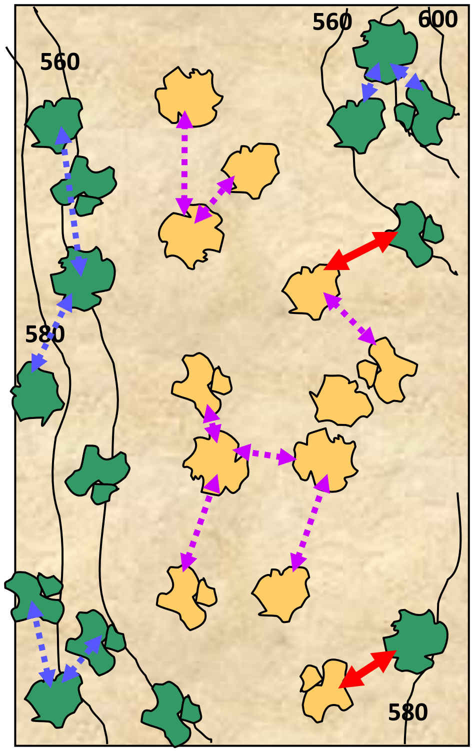
Hybridisation rates

- Proportion of *E. aggregata* compared with other eucalypt species important
  - Drop below 50:50 ratio, start to produce more hybrids

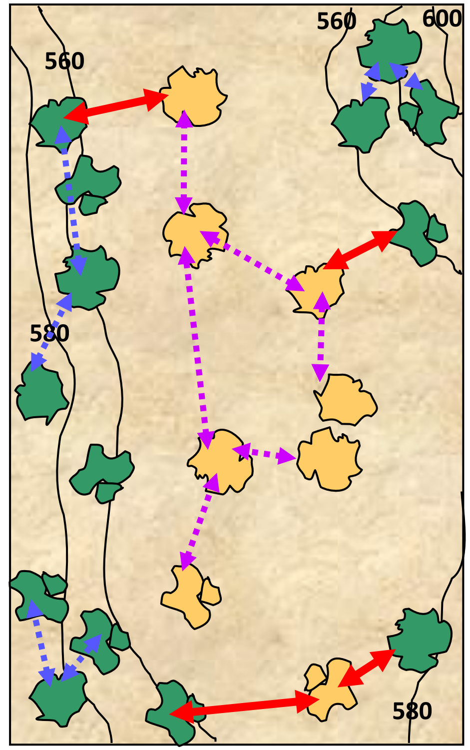
- Implications
  - Species purity?
  - Seed source?



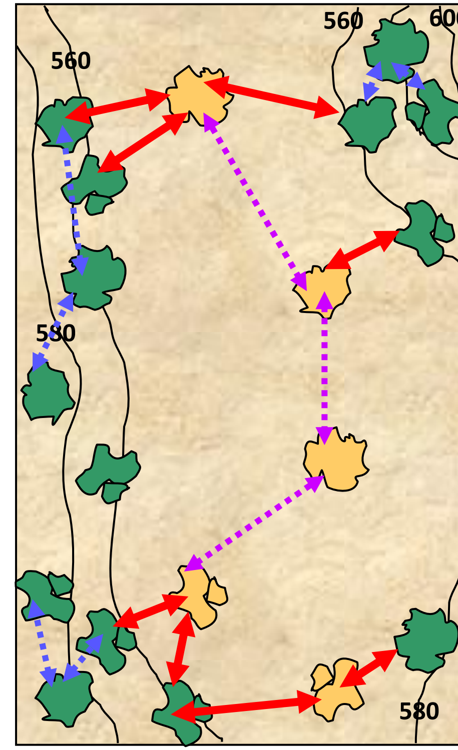
Different hybridisation rates for different remnants



12%



23%

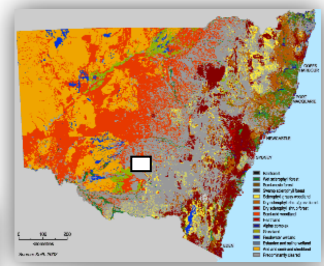


40%

Landscape connections

- Common emu bush (*Eremophila glabra*)

- Western mallee
  - Common and widespread
  - Woody shrub
  - Moderately long lived
  - Bird pollinated
  - Highly fragmented
    - Linear road verges
    - Small remnant patches
  - Self-incompatible?

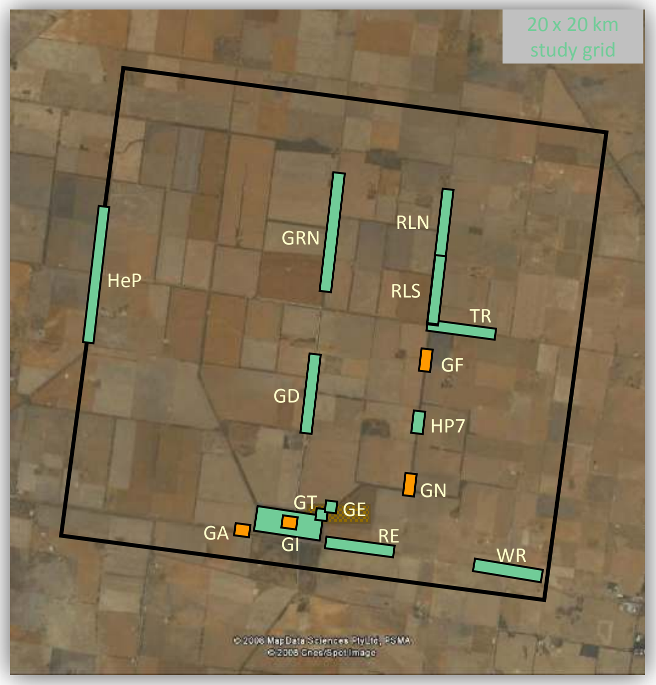


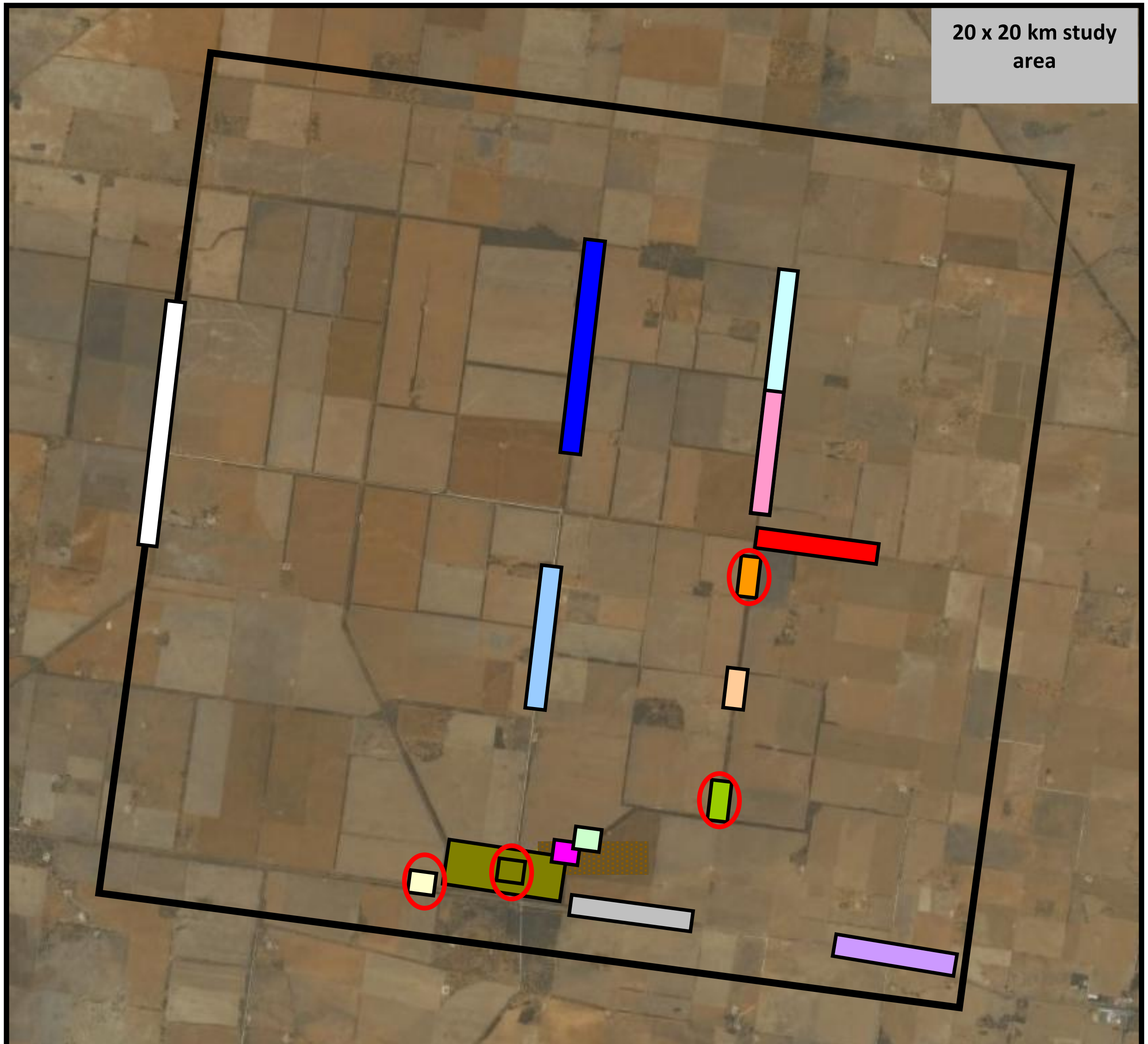




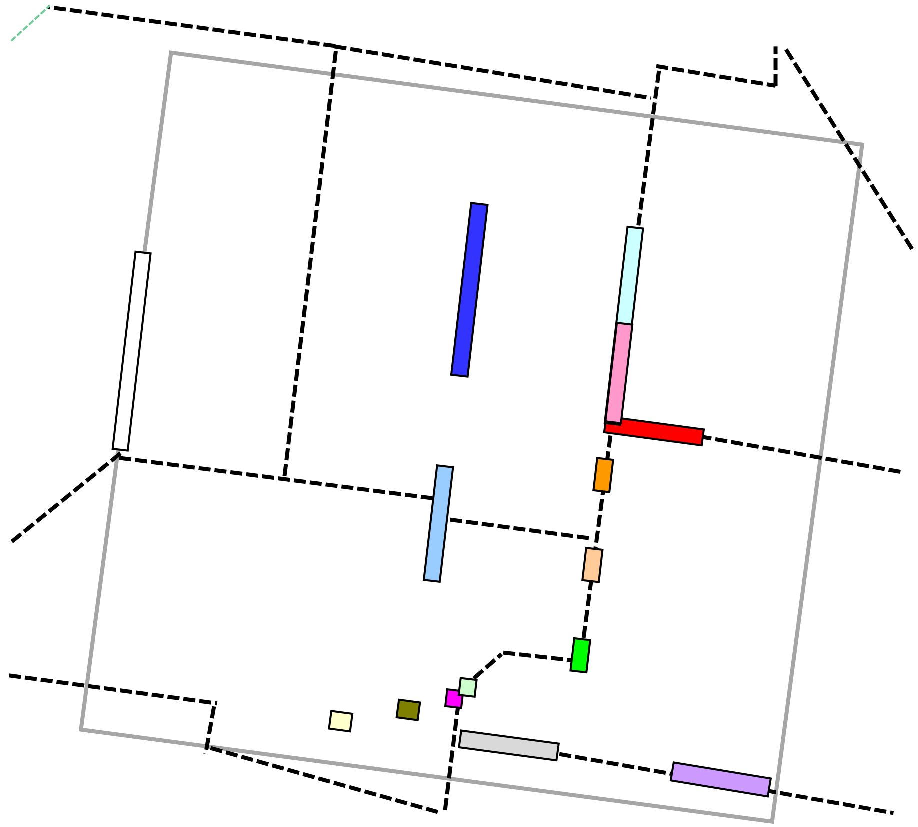
Landscape connections

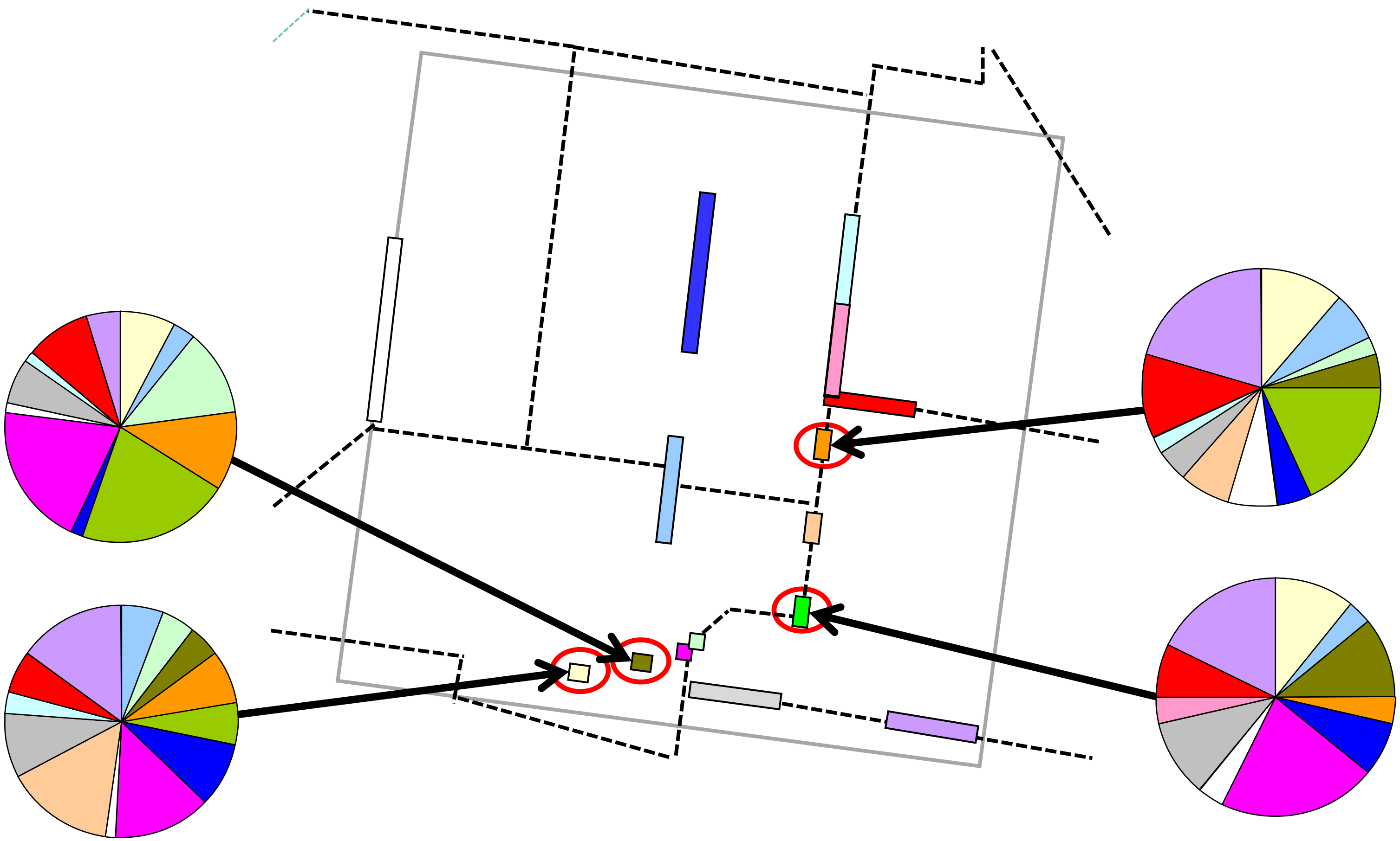
- 20 x 20 km grid
  - Exhaustive search – 15 populations, counted and mapped
- Sampled each population
- Four focal sites (orange)
  - Self-pollination
  - Cross-pollination:
    - Within population
    - Outside population
    - If outside, where from?



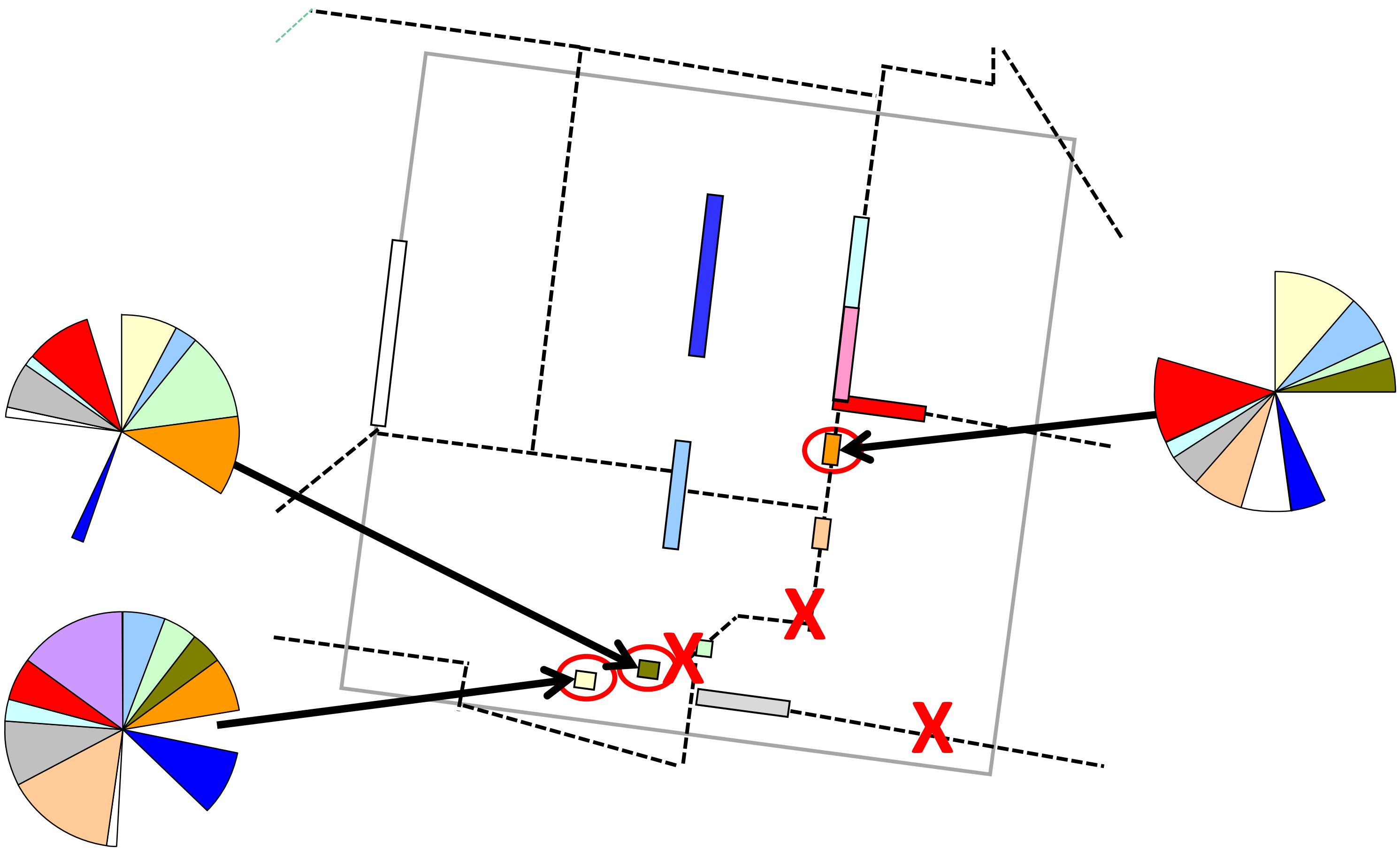


Sampled all populations, in-depth study at those circled

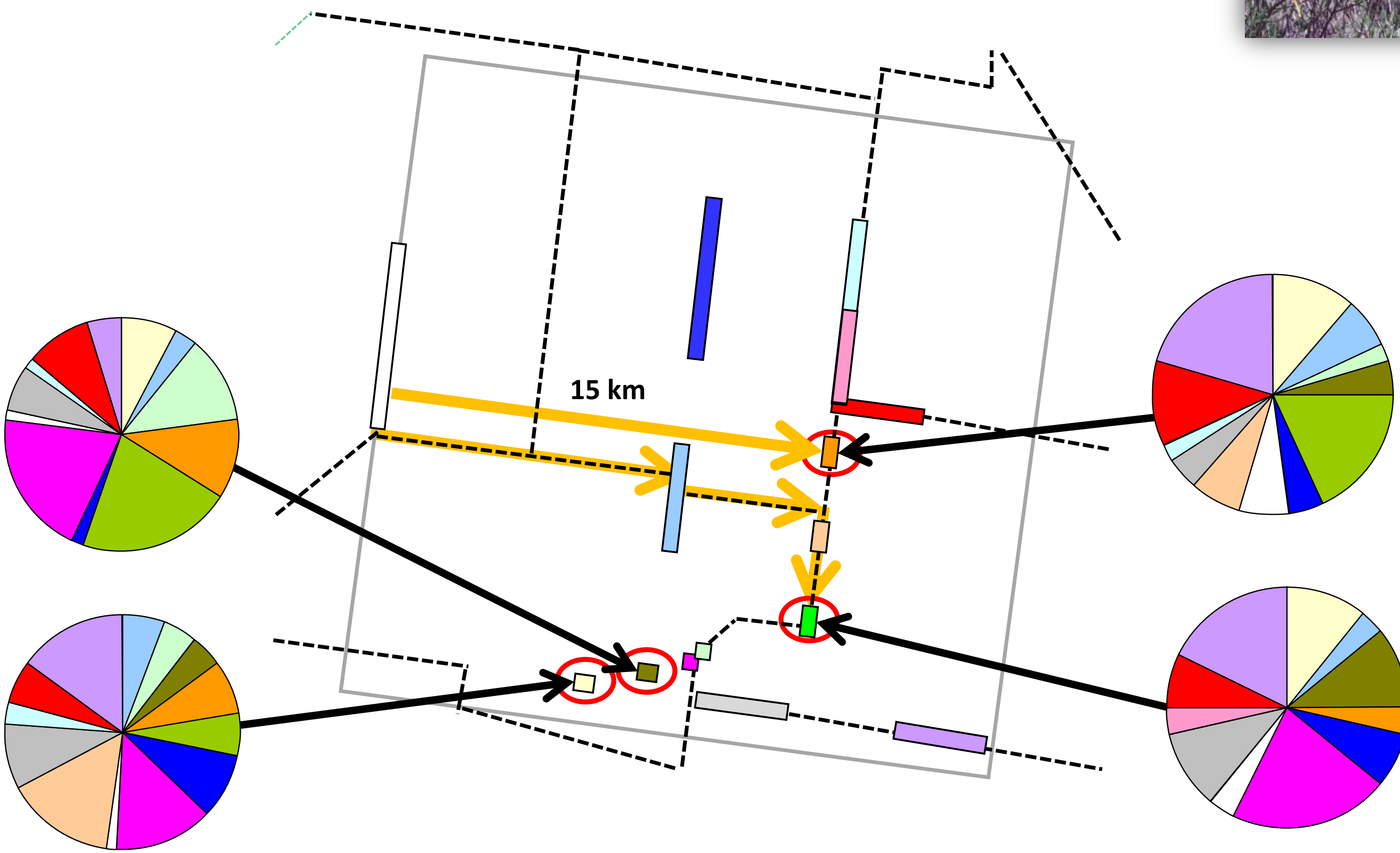




Contribution of each population to seed production in the focal sites
1. All populations contribute
2. But not equally (e.g. pink, purple, green)



Lose remnants – change dynamics of landscape
Sets up potential inbreeding effects



Also shows that birds travelling large distances and crossing several farms

Past restoration – Yellow Box (*E. melliodora*)

- Iconic, valuable – shade, shelter, honey, habitat connectivity
- Broadly distributed but can be highly fragmented
  - EEC (Commonwealth, NSW, ACT)
- Important revegetation species many years
  - Does presence = persistence?
- Poorly known life-history
  - Long-lived
  - Flowers ~every 2 years (Sept – Feb)
  - Isolated trees produce significantly less seed with poorer germination than woodland trees

Greening Australia

CSIRO

Study design

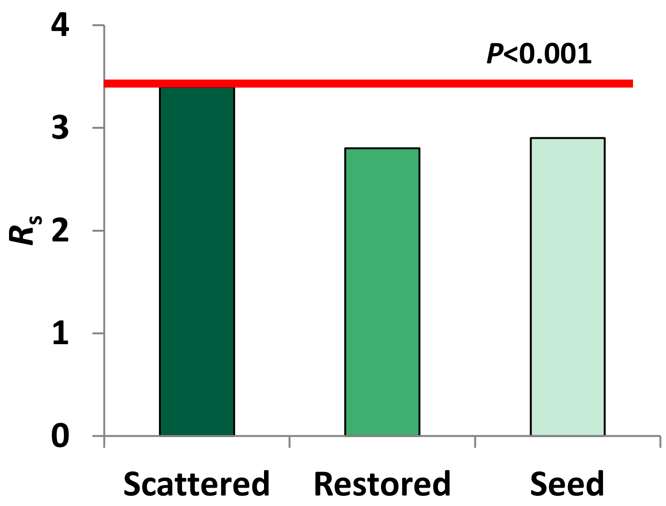
- Genetic diversity
  - Scattered (within 250 m) and restored trees
  - Seed (next generation)

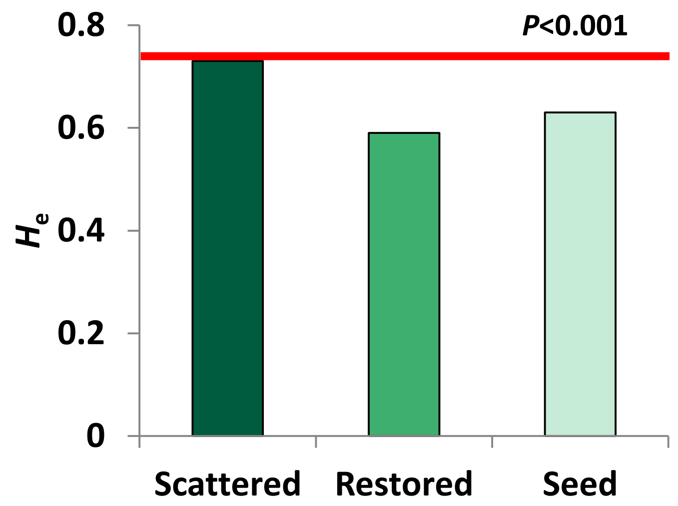
- Mating system
  - Confirmed mixed mating

- Pollen movement
  - Selfing
  - From scattered trees
  - From restored trees
  - Long distance pollination (>250 m)

Yellow Box – genetic diversity

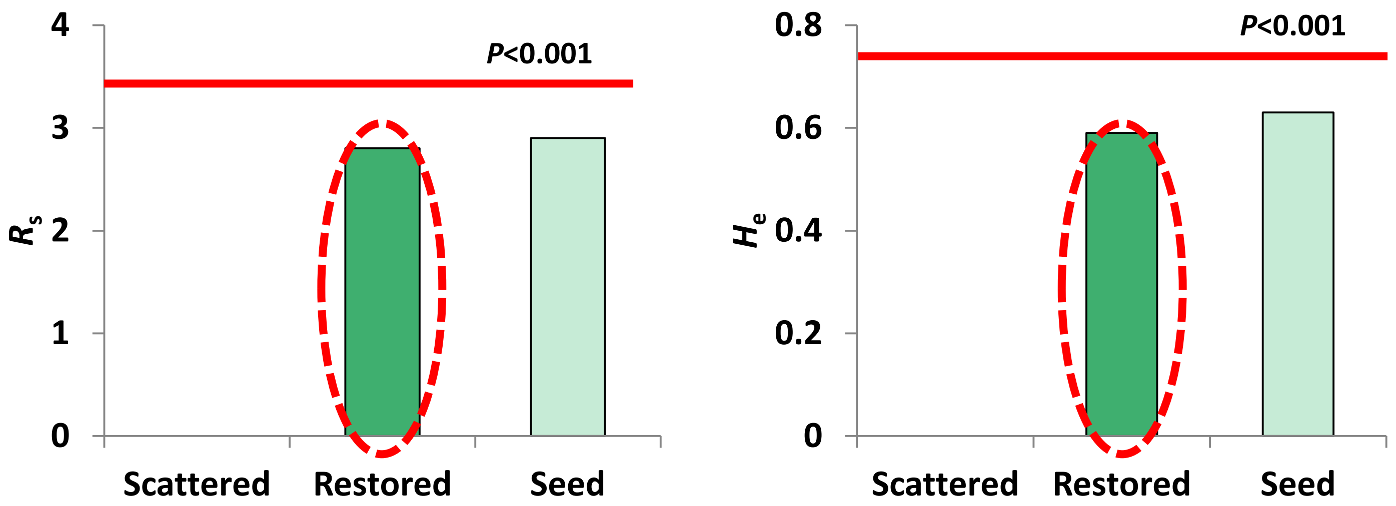
- Significantly higher genetic diversity in scattered trees





Yellow Box – genetic diversity

- Scattered trees lost over next 150-180 years
  - Landscapes genetically ‘poorer’, reduced mating pools, inbreeding



Pollen movement

- Very low selfing (1-7%)

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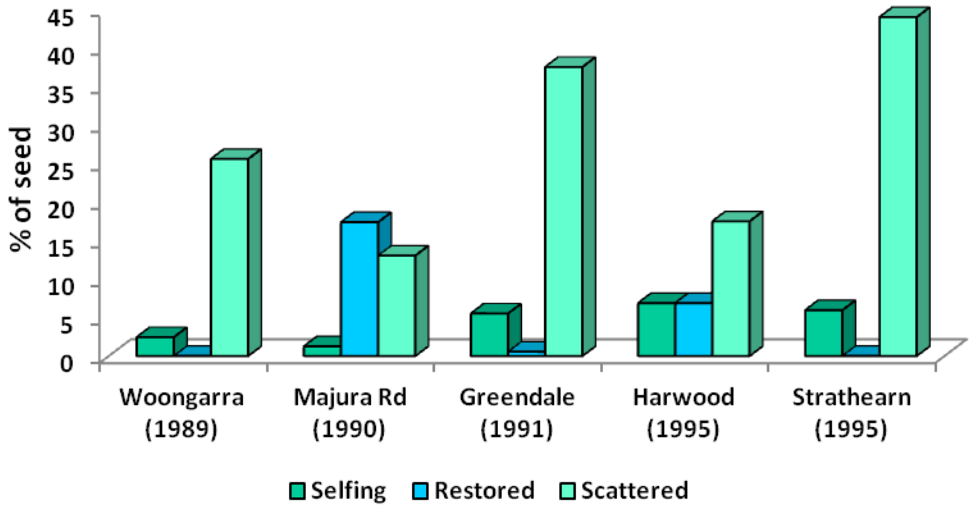
- Scattered trees within 250 m (12-41%)



Pollen movement

- Very low selfing (1-7%)
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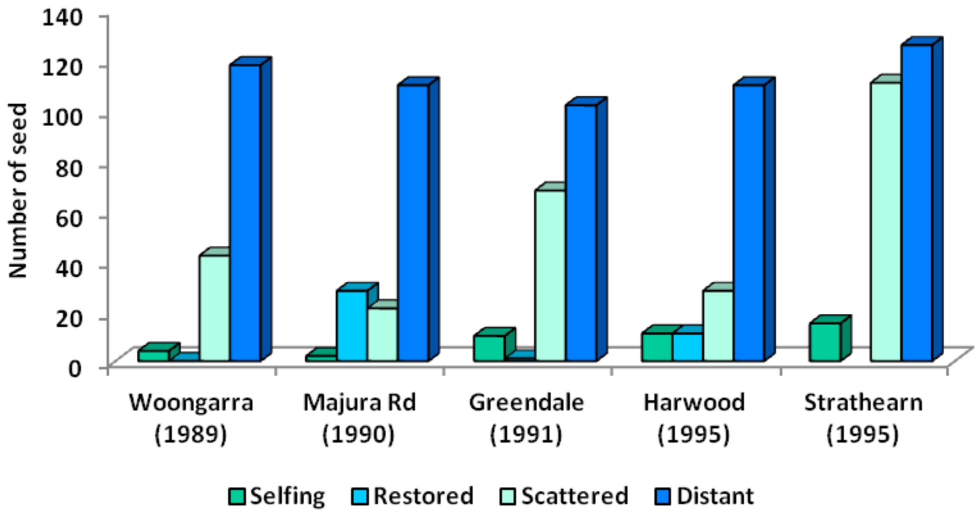
- Scattered trees within 250 m (12-41%)
- Trees beyond 250 m (47-67%)



Pollen movement

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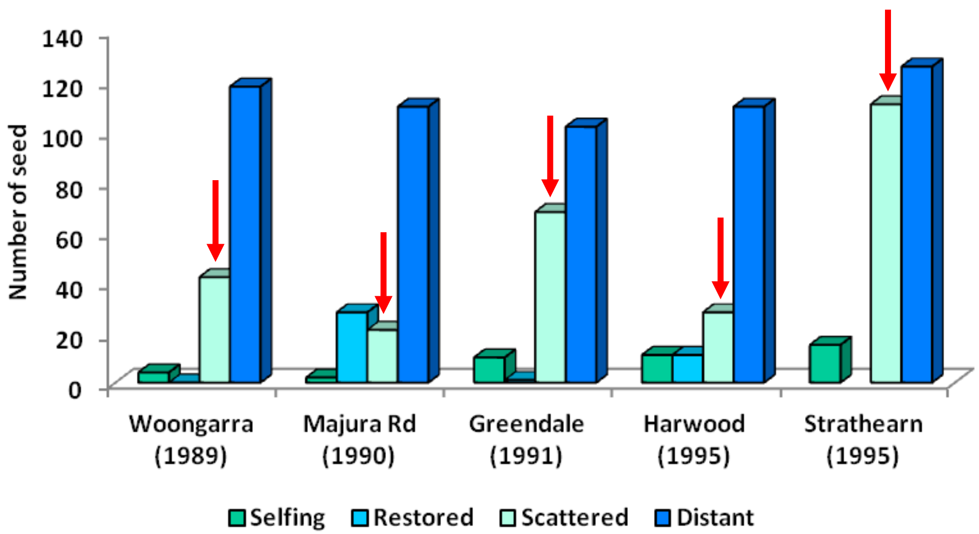


Few, scattered trees important for pollination

Restoration implications – Yellow Box

- Restoration implications
  - Results reflect past practice
    - 1-few trees used as seed sources
    - Now collect minimum 10 trees, 30 better
  - Scattered trees high value biodiversity assets
    - Maintain in landscapes as long as possible
    - Difficult: changing farming practices
  - Use scattered trees in restoration projects
    - Mix with other sources
  - Genetically reinforce existing restored sites
    - Add diversity, including from scattered trees

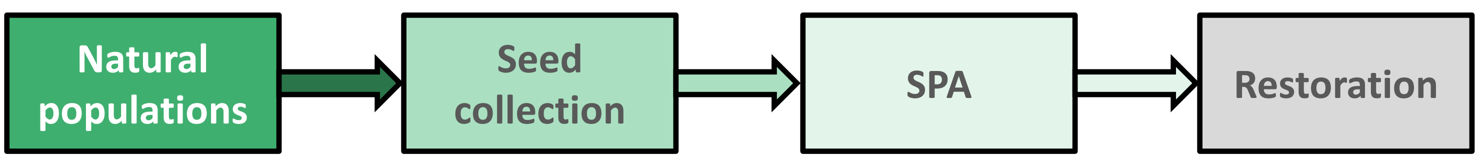
Centre for Australian National Biodiversity Research

CSIRO

Greening Australia

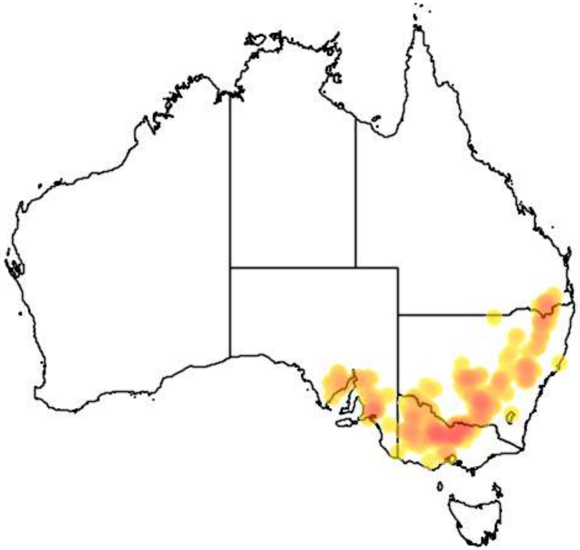
Securing seed supply

- Increasing interest in Seed Production Areas (SPAs)
  - Difficult to collect species (understorey, explosive seed dispersal)
  - Need regular source of large volumes high quality seed
    - Reduce burden native vegetation
  - Large investment
    - Longer lived species take many years to produce a return
    - Need to be extremely confident in seed quality
  - Inadvertent genetic bottlenecks during transition from natural populations to restored sites



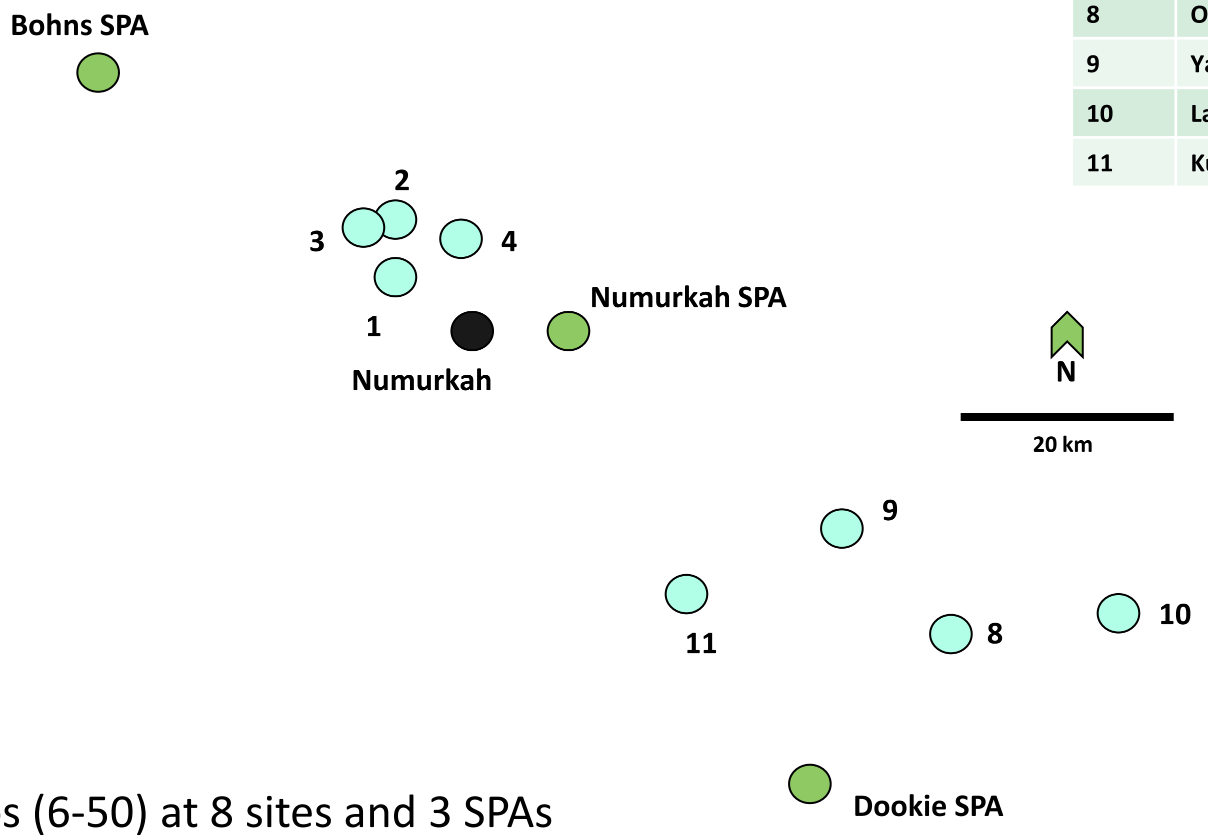
Acacia montana (Mallee Wattle)

- Rounded shrub to 4 m
- Distributed SA, Vic, NSW and Qld
- Frost hardy (frosts to -7 C)
- Hybrids (*A. aspera*) in Bendigo region



Populations sampled

No.	Name
1	Boothroyds Rd, Numurkah
2	Boothroyds Rd, Katunga
3	Randalls Rd, Katunga
4	Goulburn Valley Hwy, Katunga
8	Oliver Rd
9	Yabba North
10	Lake Rowan
11	Kull Rd



Sampled shrubs (6-50) at 8 sites and 3 SPAs
Developed SSR markers (7)

SPA source material

No.	Name
1	Boothroyds Rd, Numurkah
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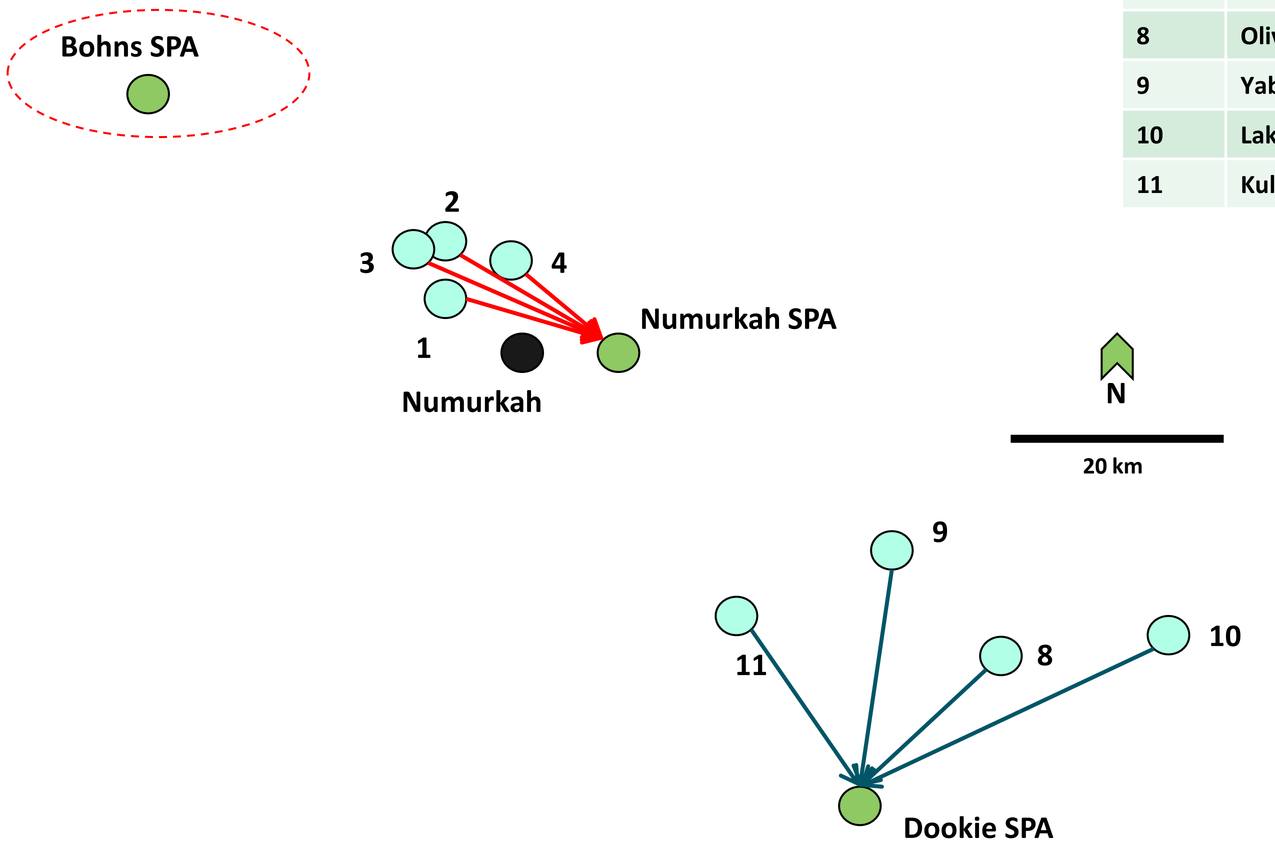

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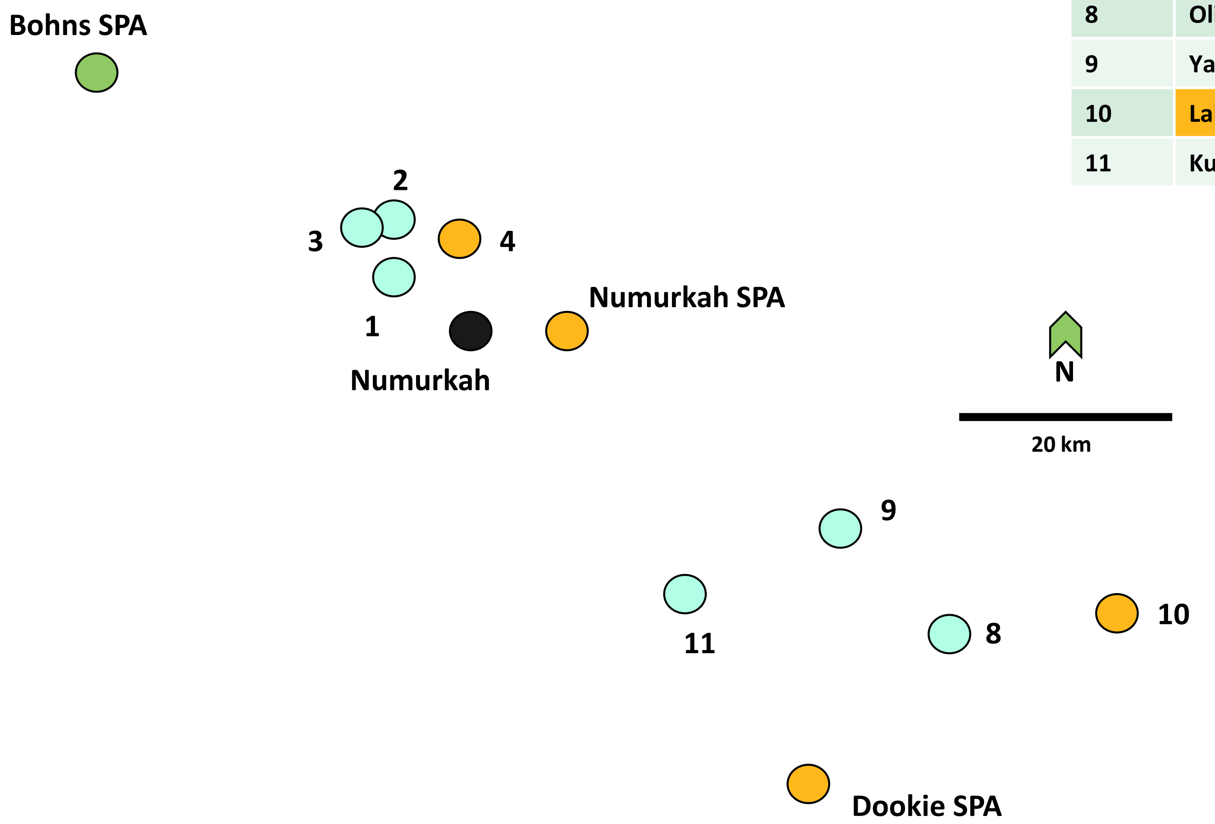
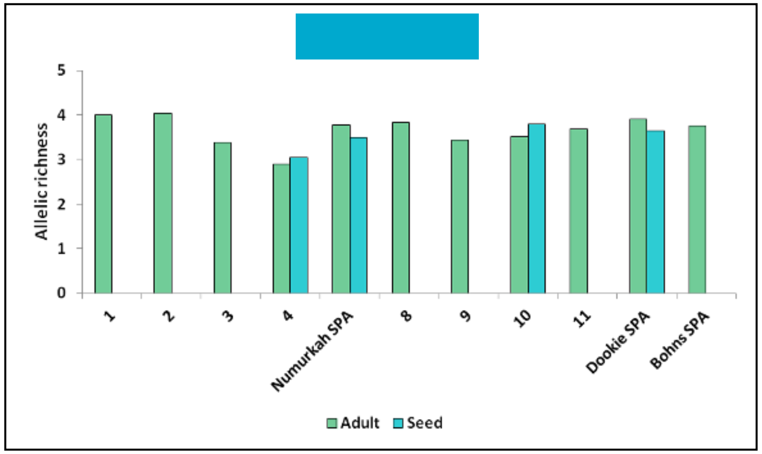
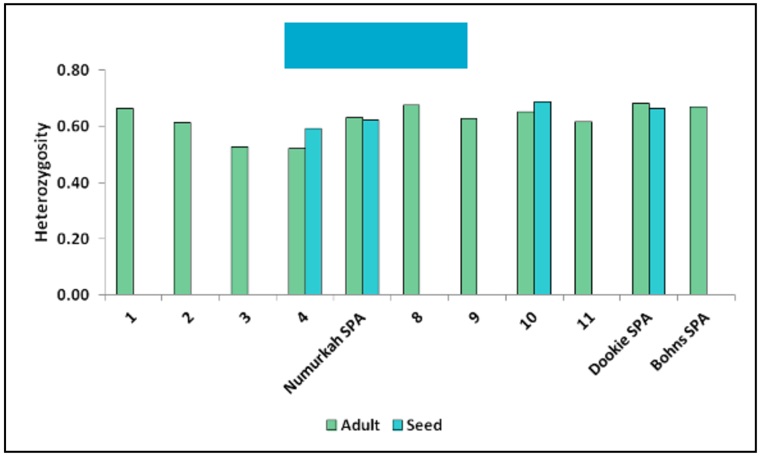


Sampled seed at 2 Wild pops and 2 SPAs

Genetic diversity

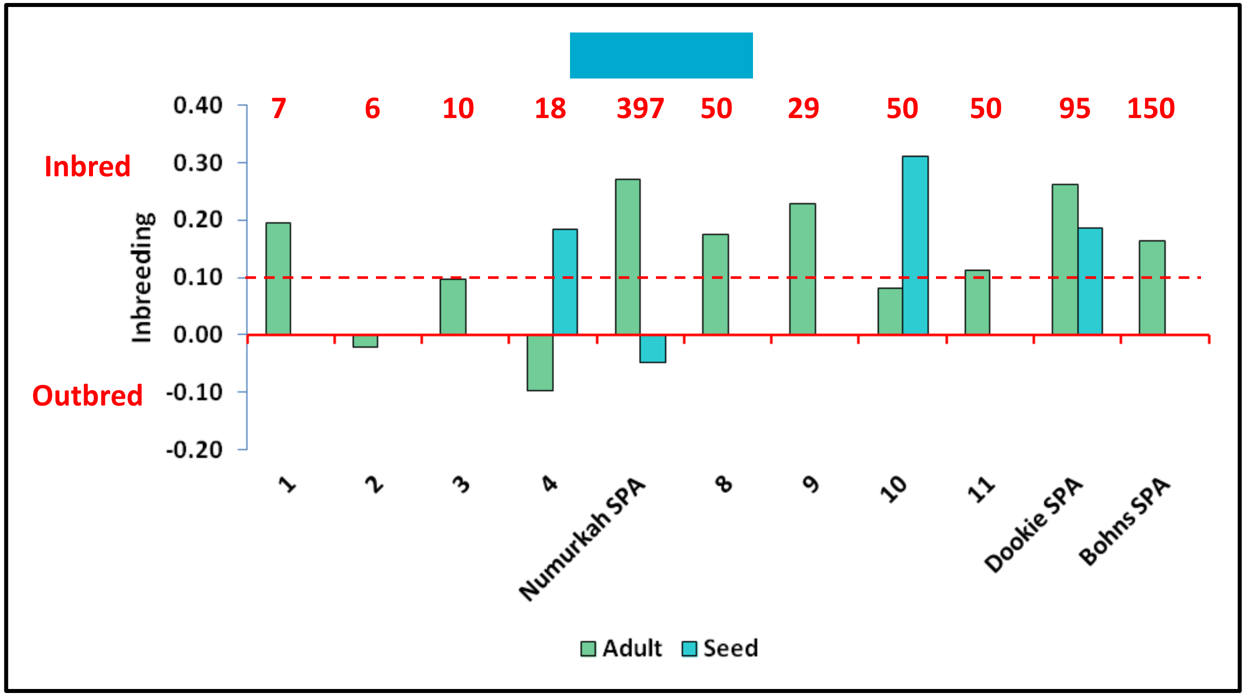




Allelic richness and heterozygosity are generally comparable

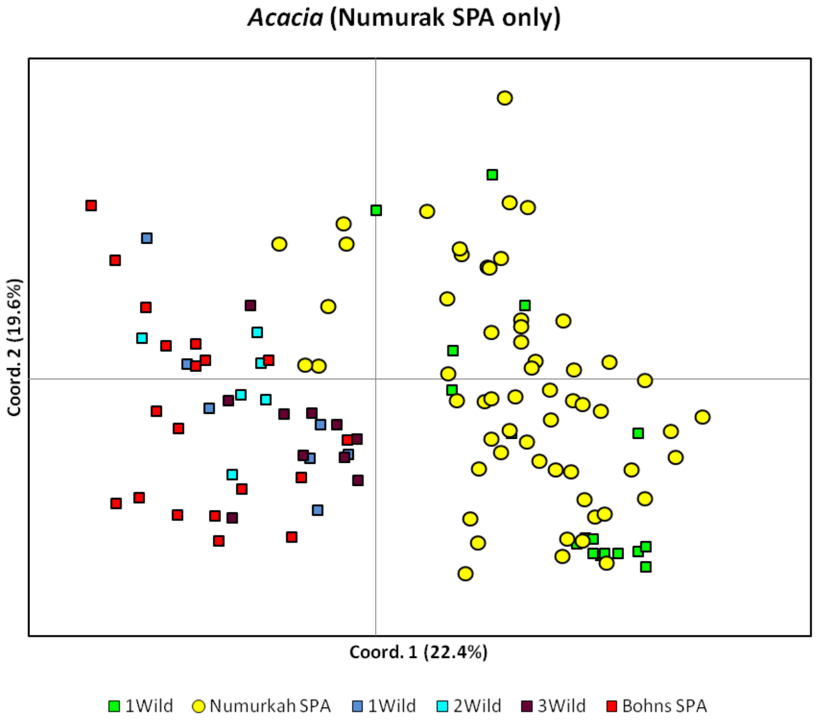
- among populations (green)
- between shrubs (green) and their seed (blue)

Inbreeding

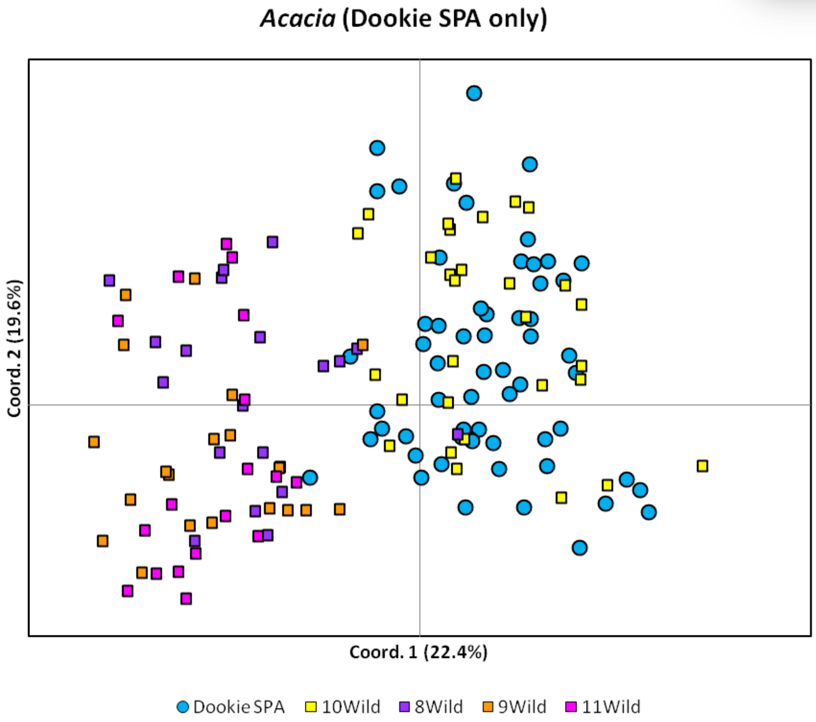


- Many wild populations and all SPAs show inbreeding
- All seed except at Numurkah SPA also inbred
- Inbreeding generally reflects small population sizes
    - Use limited genetic diversity in SPA, large no. plants doesn't help
    - Bringing inbred populations together does help e.g. Numurkah SPA

Genetic representation

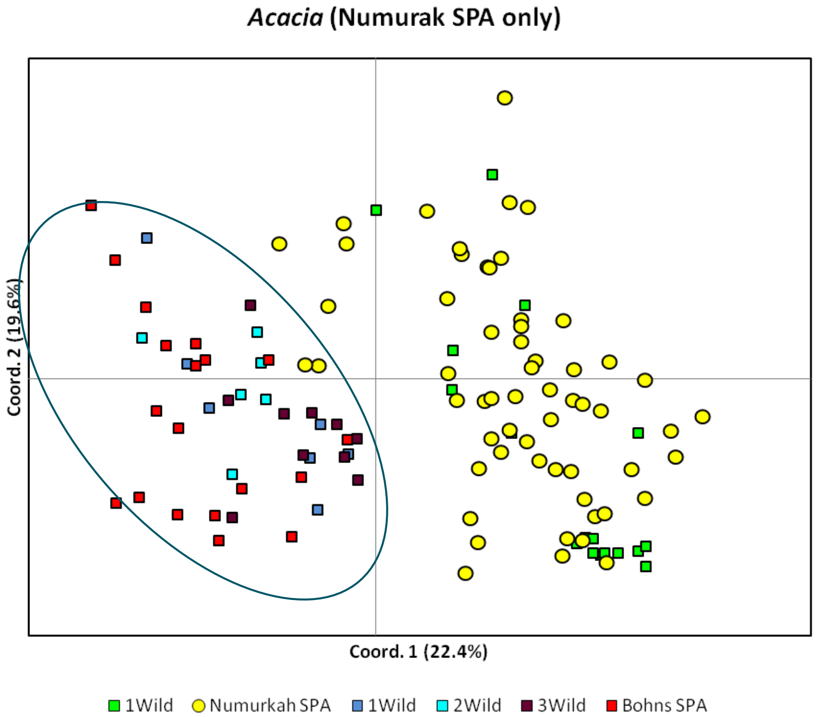


Primarily pop 1 samples



Primarily pop 10 samples

Genetic representation



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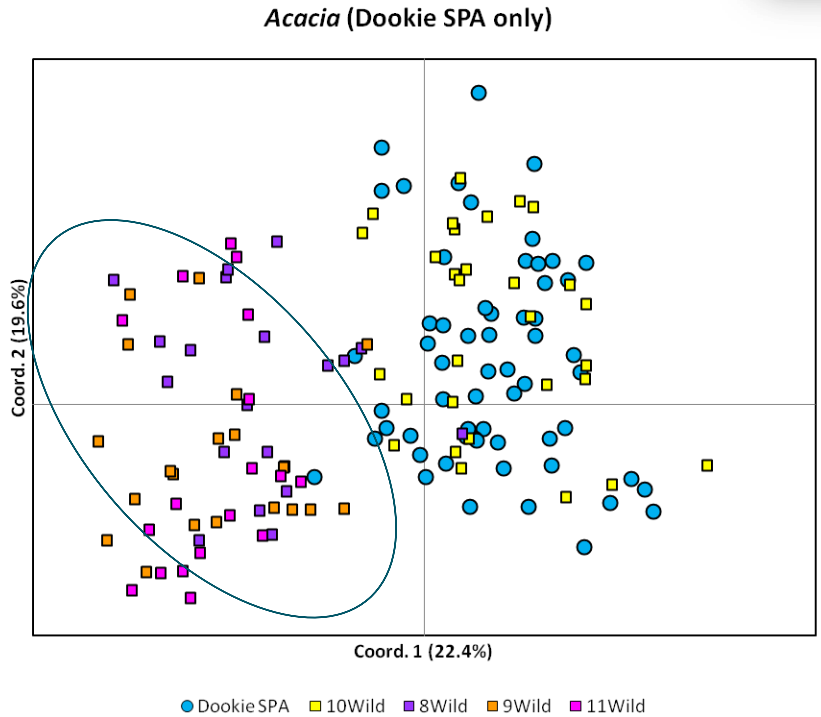

Primarily pop 10 samples

Acknowledgements

- CSIRO - Tara Hopley, Lan Li, David Filed, Andrew Young
- Greening Australia = Bindi Vanzella, Graham Fifield, Sue Streatfield, landowners and collectors
- GB CMA - Janet Hagen, Cathy Olive, Liz Evans, Kim Magnay, Andrew Sands, Andie Guerin, Woka walla NRM crew, Neil Morris, Martin Driver, Sue Logie, Andrew Saunders, RADCOM crew, Goulburn Broken CMA, Australian Government, Sarah Roberts, Murray Seedbank, Goulburn Broken Indigenous Seedbank, Euroa Arboretum, Murray Local Land Services.

Thank you