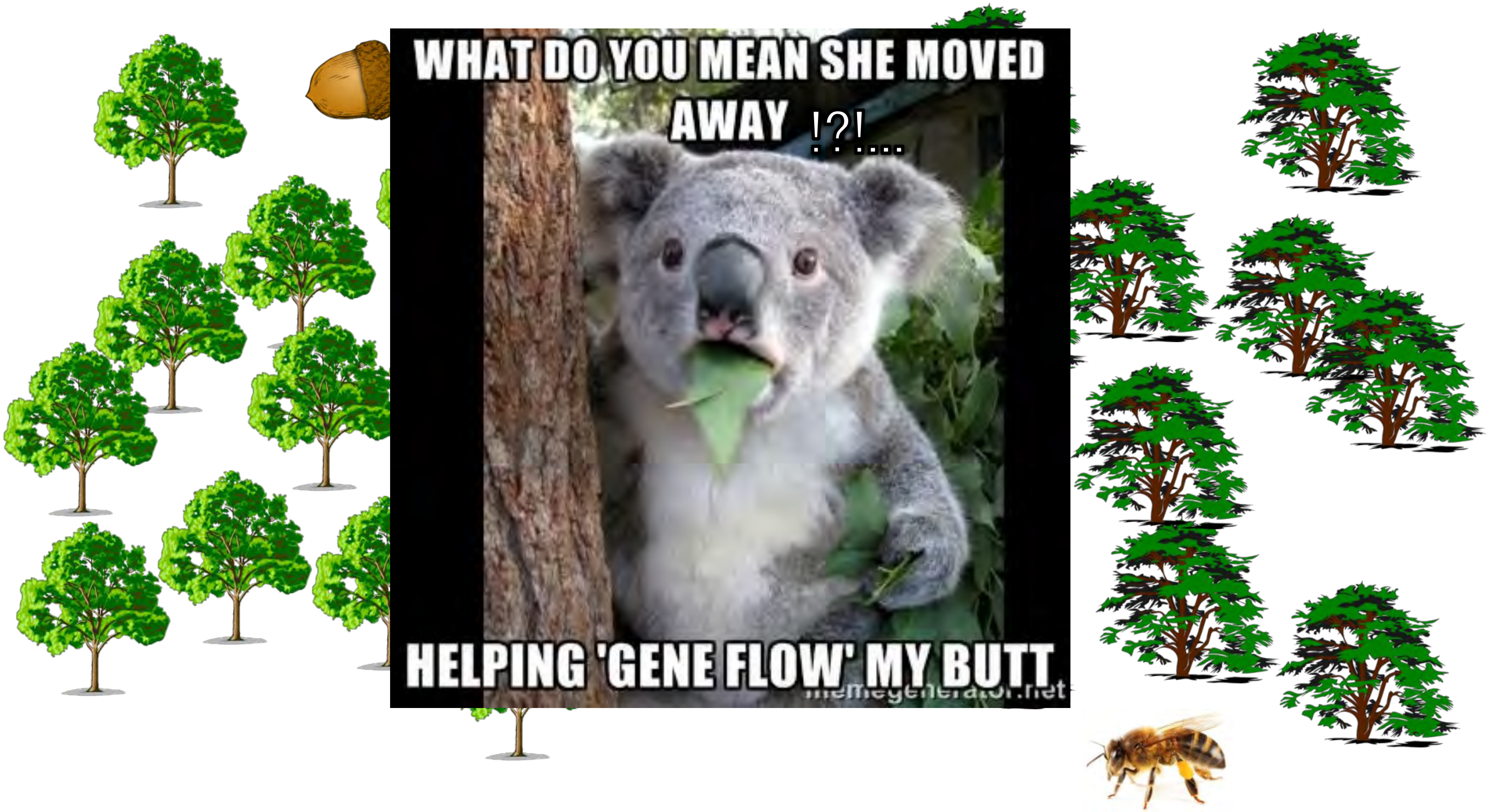
Exotic gene flow from plantations to native eucalypts

Matthew Larcombe, University of Tasmania
Supervisors: Brad Potts & René Vaillancourt

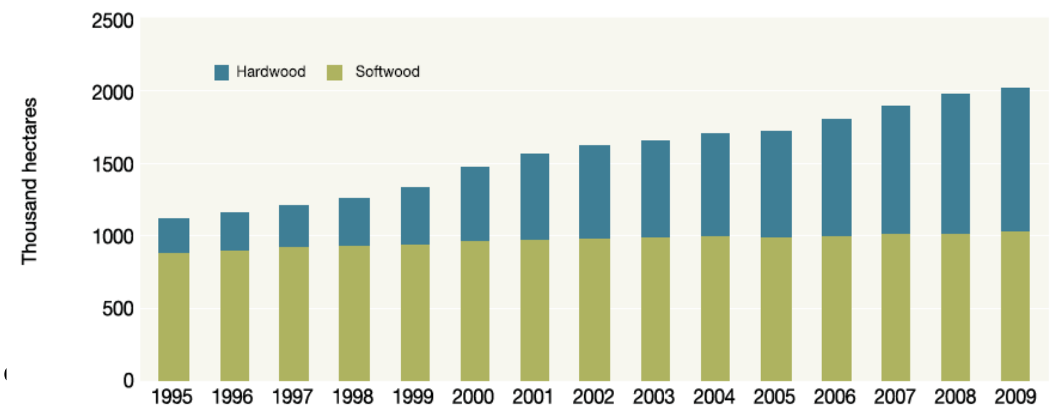
Gene flow is a natural process

The movement of genetic material between populations or species. In plants, usually the movement of seed or pollen.



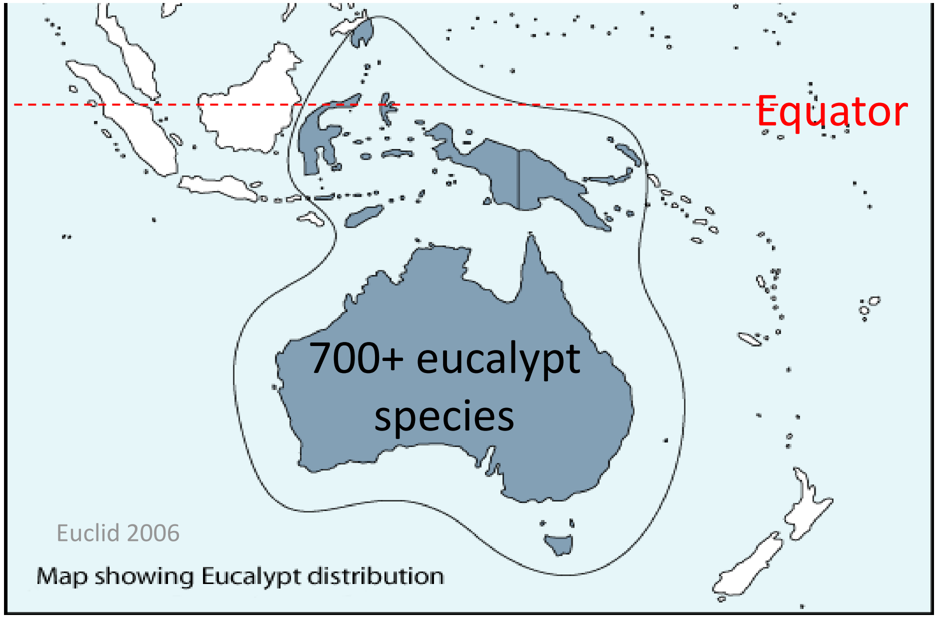
Eucalypt plantations in Australia

Gavran and Parsons 2011



Large-scale hardwood plantation expansion starting in 1990s

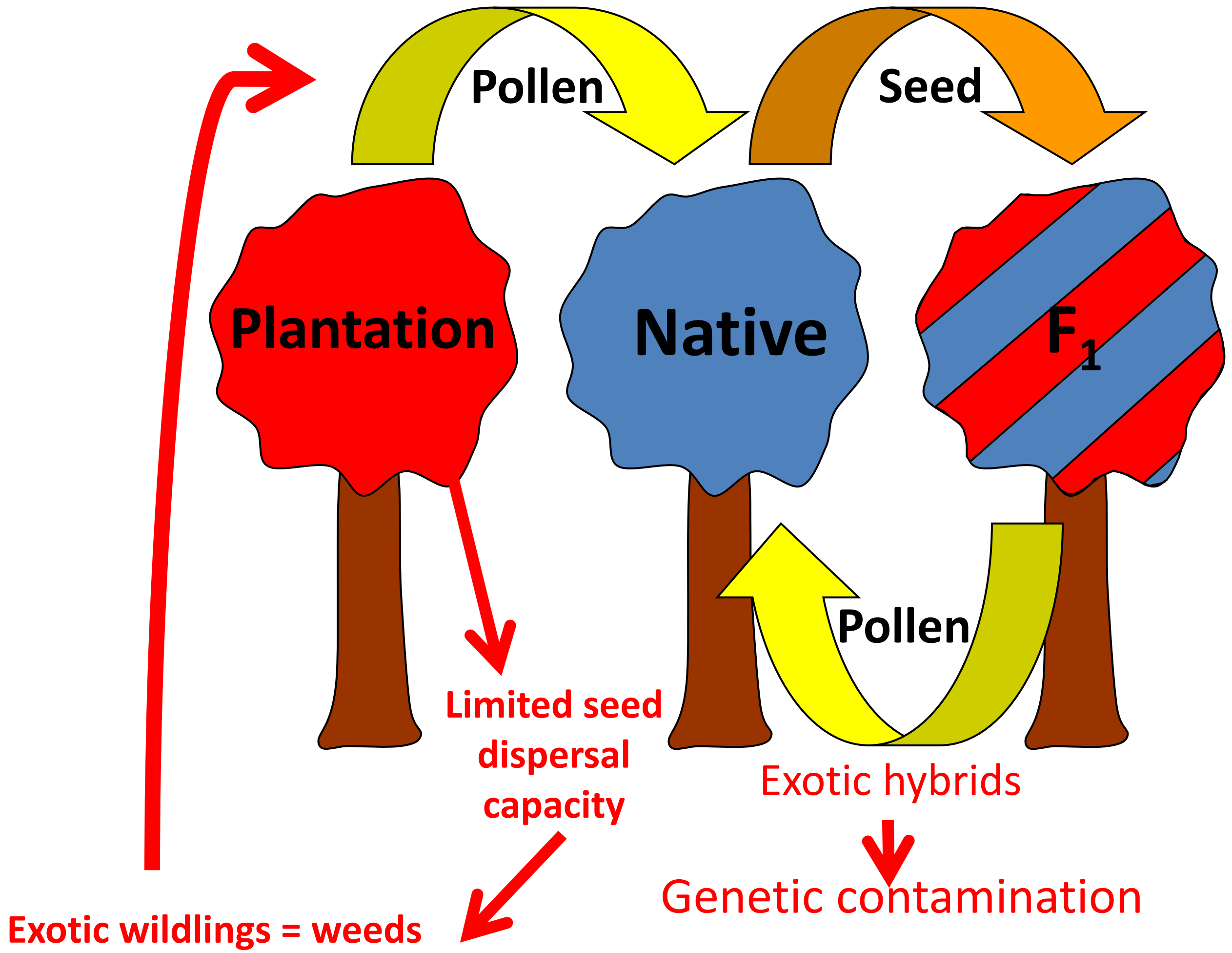
973,000 ha in 2010



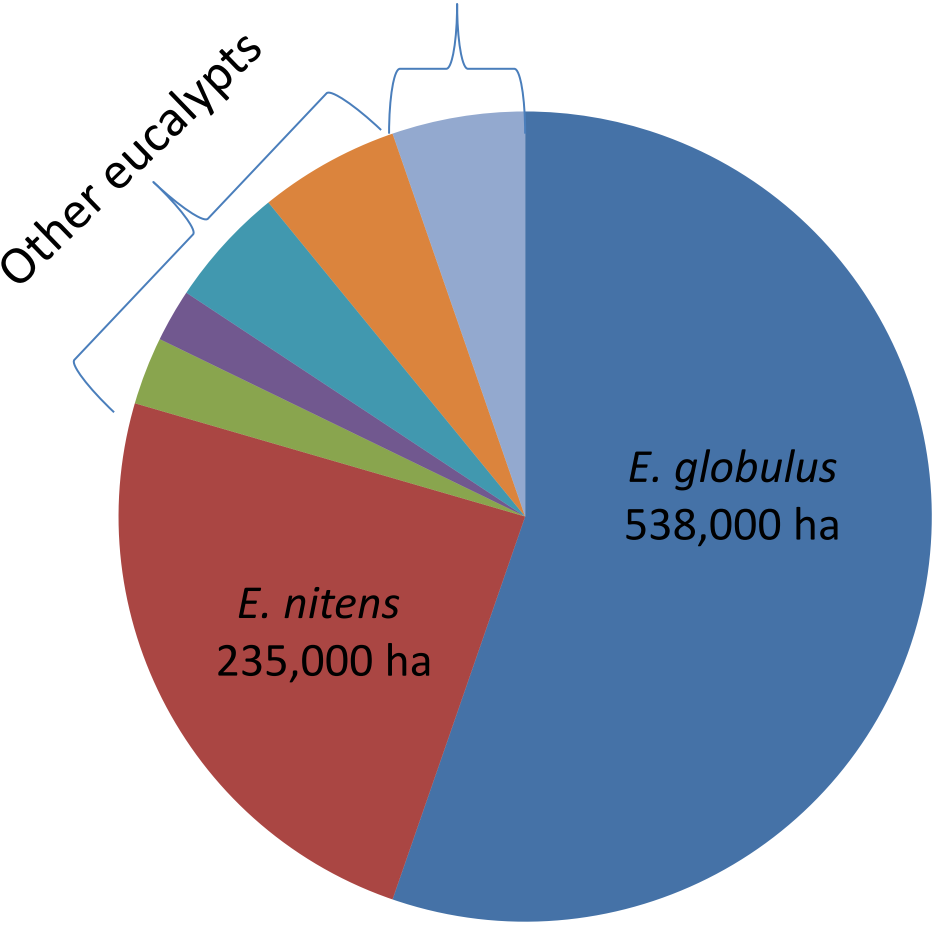
Pollen-mediated gene flow is of concern

- eucalypts are the dominant forest type in Australia
- often weak reproductive barriers between species
- pollen dispersal is widespread compared with seed
- minimising gene flow from plantations is an indicator of sustainable forest management

The exotic gene flow process



The Australian plantation estate is dominated by *E. nitens and E. globulus*



Gavran and Parsons 2011

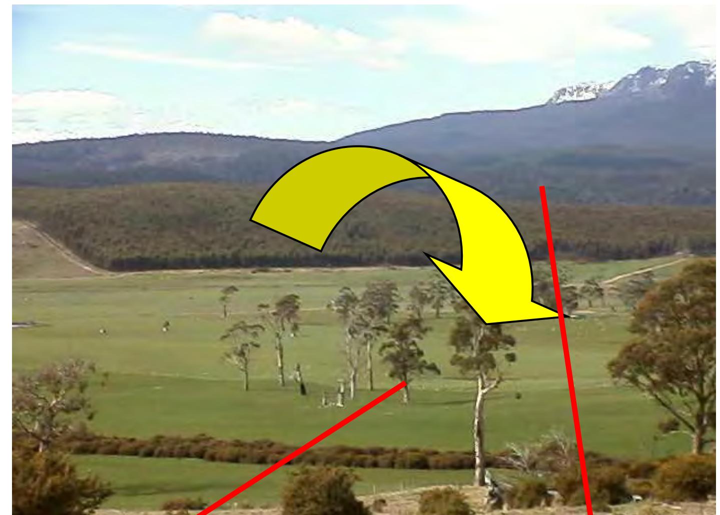
- Together make up ~ 80 % of the hardwood estate
- Now planted well outside their native range

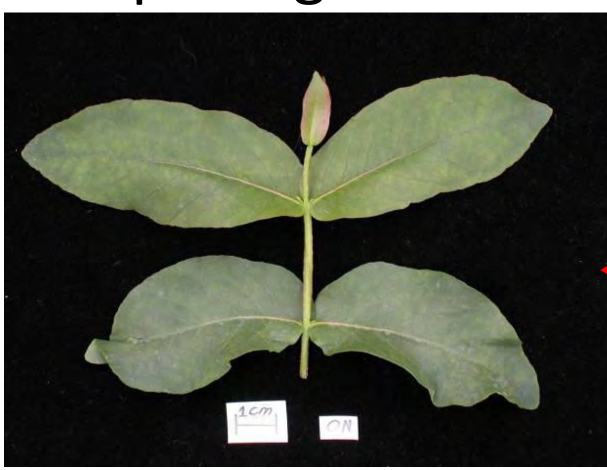
E. globulus

E. nitens

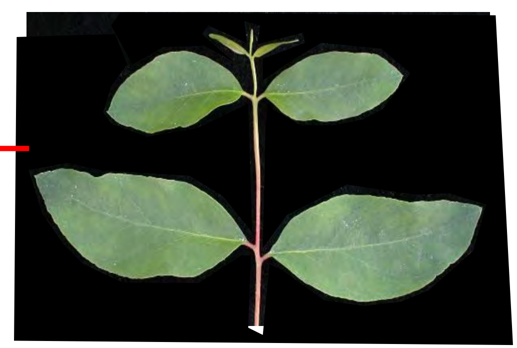
Eucalyptus nitens in Tasmania – 16 years of exotic gene flow research

- *E. nitens* is exotic to TAS
- Main plantation species (207,000 ha) Gavran and Parsons 2011
- 17 of the 30 native species are possibly at risk
- Morphological markers





E. ovata x nitens hybrid



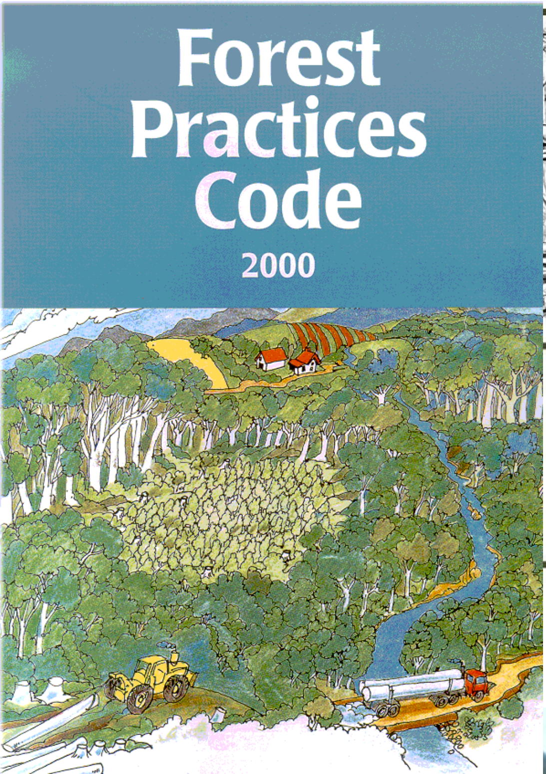
E. ovata

x

E. nitens

E. nitens risk assessment protocol

Slide by Brad Potts 2010



Flora Technical Note No. 12:

Management of gene flow from plantation eucalypts

FPA
FOREST PRACTICES AUTHORITY

2010

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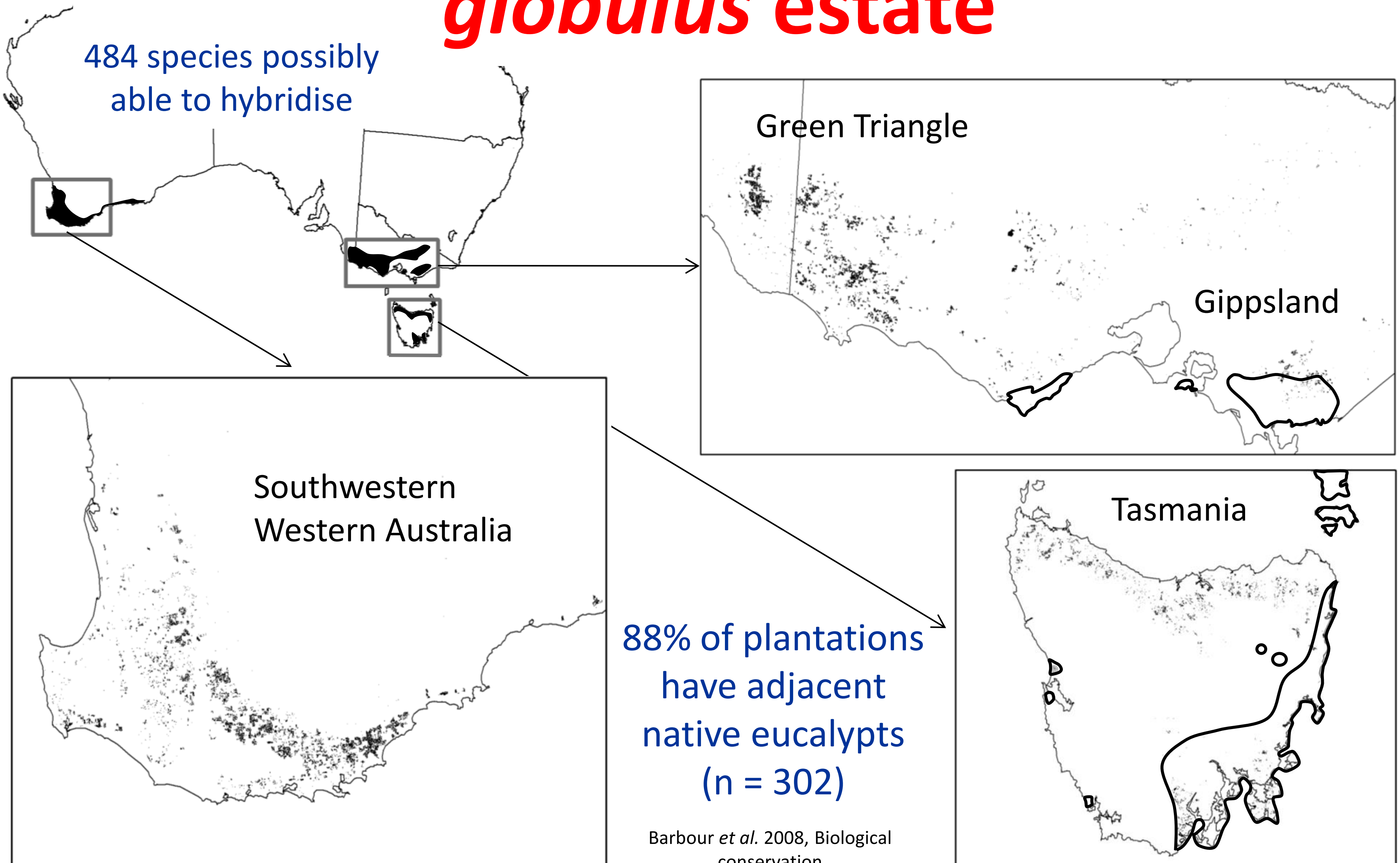
Techn

Hybridisation risk	*Planning measures*	*Monitoring and control measures*
Minimal risk	No special planning requirements	No formal monitoring requirements
Low risk	No special planning requirements	Regular monitoring for established hybrid seedlings[1] and hand-weeding programs instigated if hybrids found.
Moderate risk	No special planning requirements (however note possible measures discussed in the text below)	Regular monitoring for hybrid seedlings plus breeding system monitoring (explained in dot point 7 in the text below). Hand-weeding programs instigated if hybrids found.
High risk	Do not establish or re-establish eucalypt plantations without consultation with FPA. (Substantial planning and monitoring obligations may be required).	

So what about the much larger *E. globulus* estate



Barbour *et al.* 2008, Biological conservation

PhD questions:

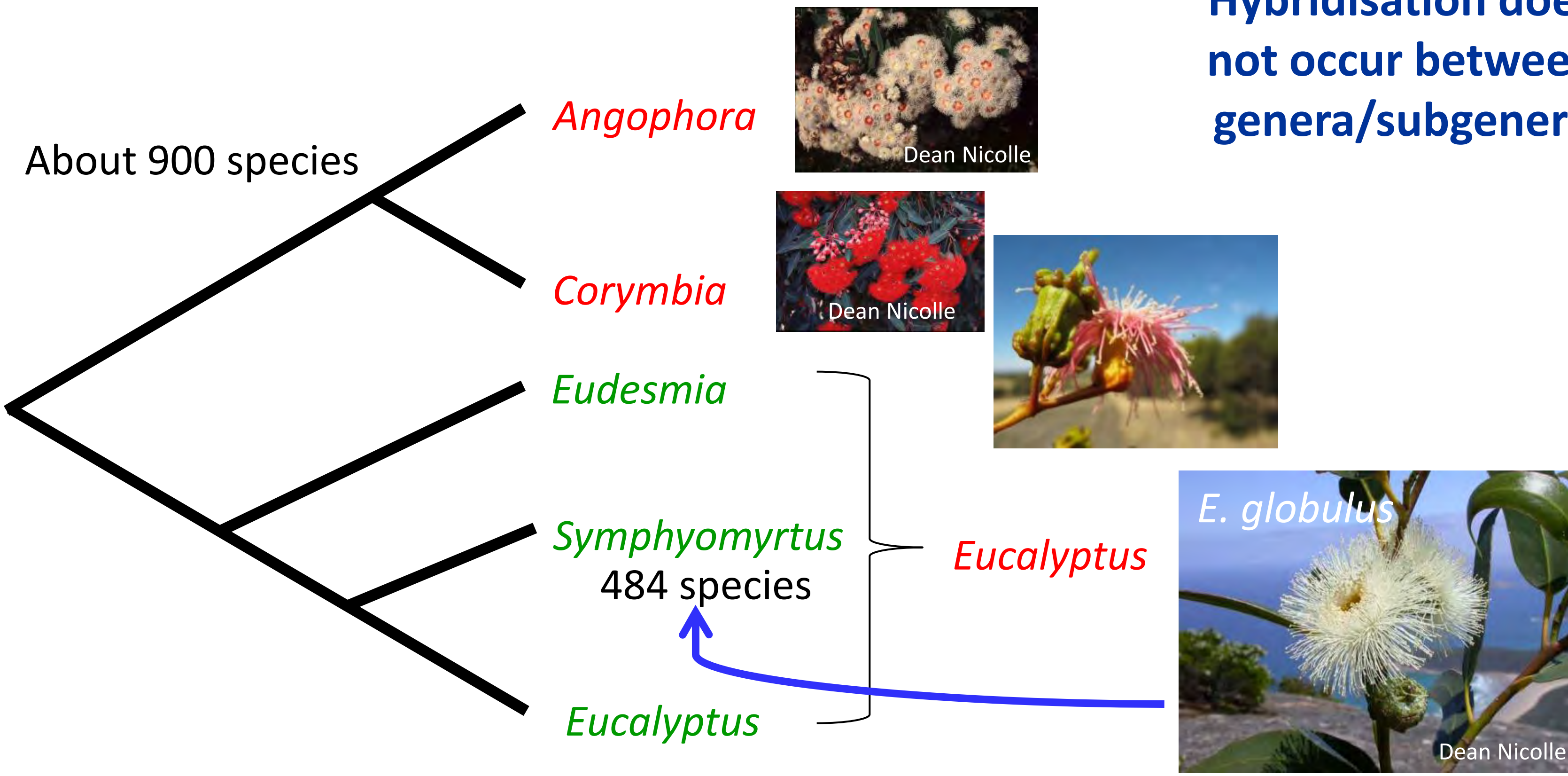
1. Which species and groups of species can hybridise with *E. globulus*

2. Case study of an *at-risk* species, *Eucalyptus ovata*:

    1. Do source sink relationships affect the likelihood of gene flow: are small remnants at greater risk?
    2. How common is hybrid establishment ?
    3. How fit are hybrids in relation to their pure native siblings?

3. Is seed-mediated gene flow from *E. globulus* plantations a problem?

1: Which species can hybridise with *E. globulus?*



Hybridisation does not occur between genera/subgenera

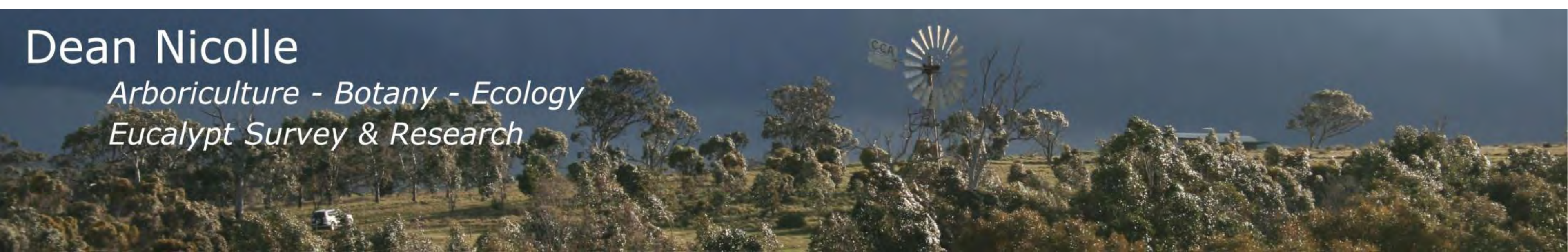
	Genus	> subgenus	> section	> series
% natural hybrids	- 0%	0%	9%	39%

Griffin *et al.* 1988, *Australian Journal of Botany*, **36**, 41-66.

1: Which species can hybridise with *E. globulus?*

Crossing:

- Currency Creek Arboretum (>900 taxa)
- > 7000 flowers crossed with *E. globulus* pollen
- 100 species
- 13 taxonomic sections
- Subg. *Symphyomyrtus* (96 spp.)
- Subg. *Eucalyptus* (2 spp.)
- Subg. *Eudesmia* (1 sp.)
- *Corymbia* (1 sp.)



1: Which species can hybridise with *E. globulus*?

Crossing:

Dorothy Steane

- Curren… tum
- > 7000 … d
- 100 sp…
- 13 taxonomic sections

Rebecca Jones

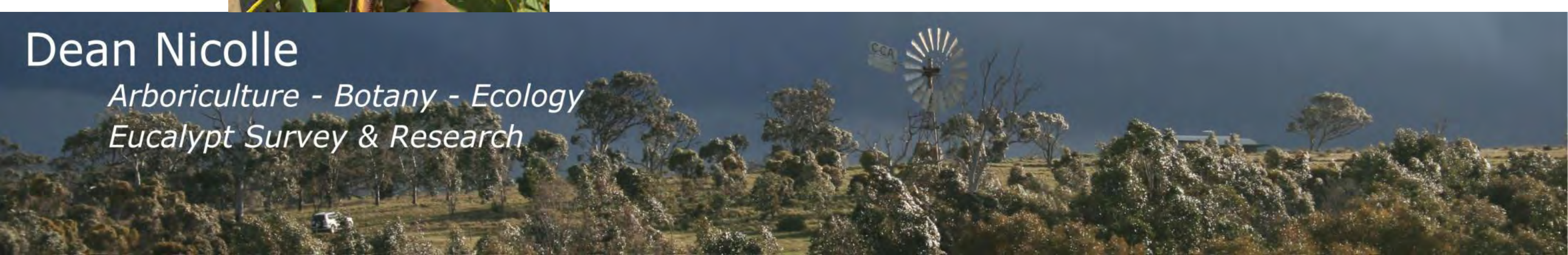
- Subg. S… (96 spp.)
- Subg. E… p.)
- Subg. E…
- *Corymb*…

Phylogenetics:

Genome-wide DArT markers:

(1) 8350 markers covering all sections but not all species

(2) 5050 markers covering ca. 200 spp. (Sections *Maidenaria*, *Latoangulatae* and *Exertaria*) including the 22 most closely related species in this study

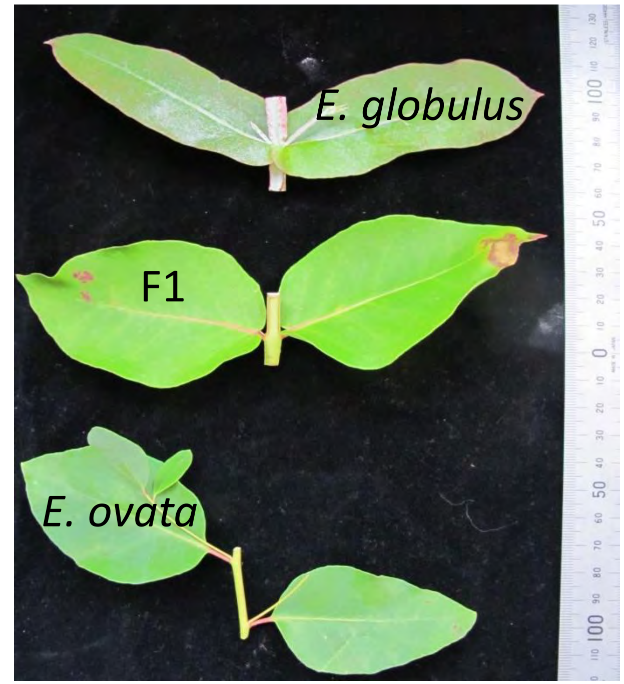


1. Two crossing approaches

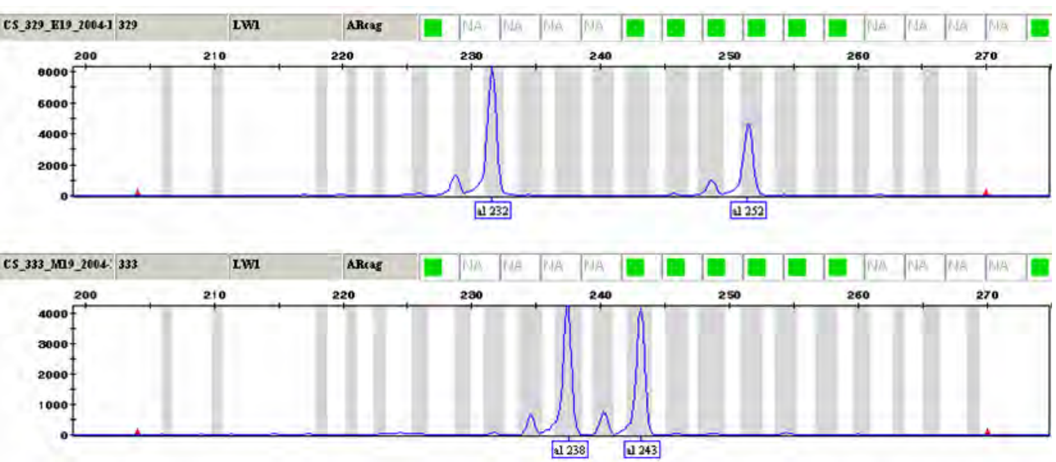
- "**Supplementary**" pollination mimics natural pollination
- "**Cut-style**" pollination avoids (pre-zygotic) incompatibilities in the style and receptivity problems

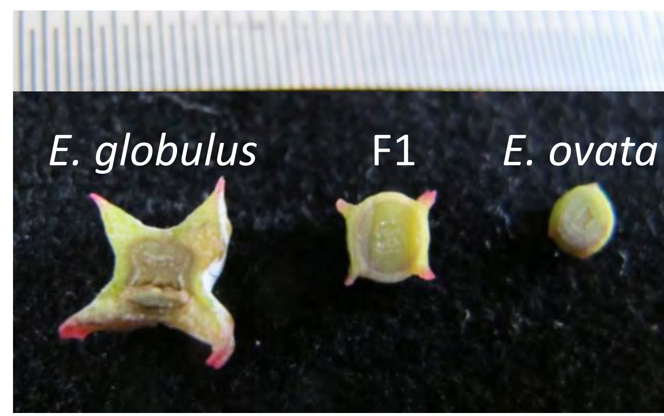


1. Hybrids identified with morphology and validated with molecular markers



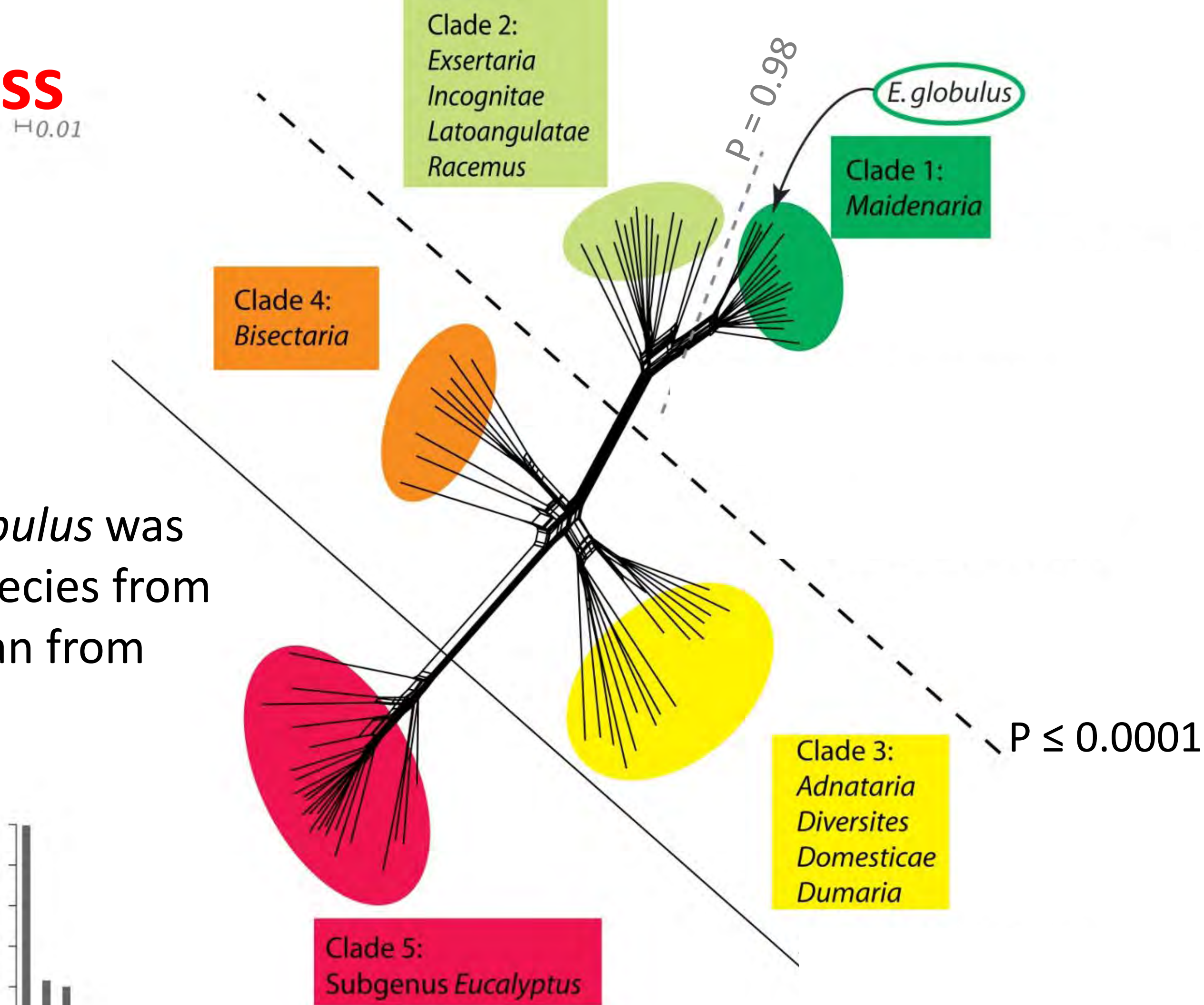
10 microsatellite loci were used to match alleles from each parent in hybrids

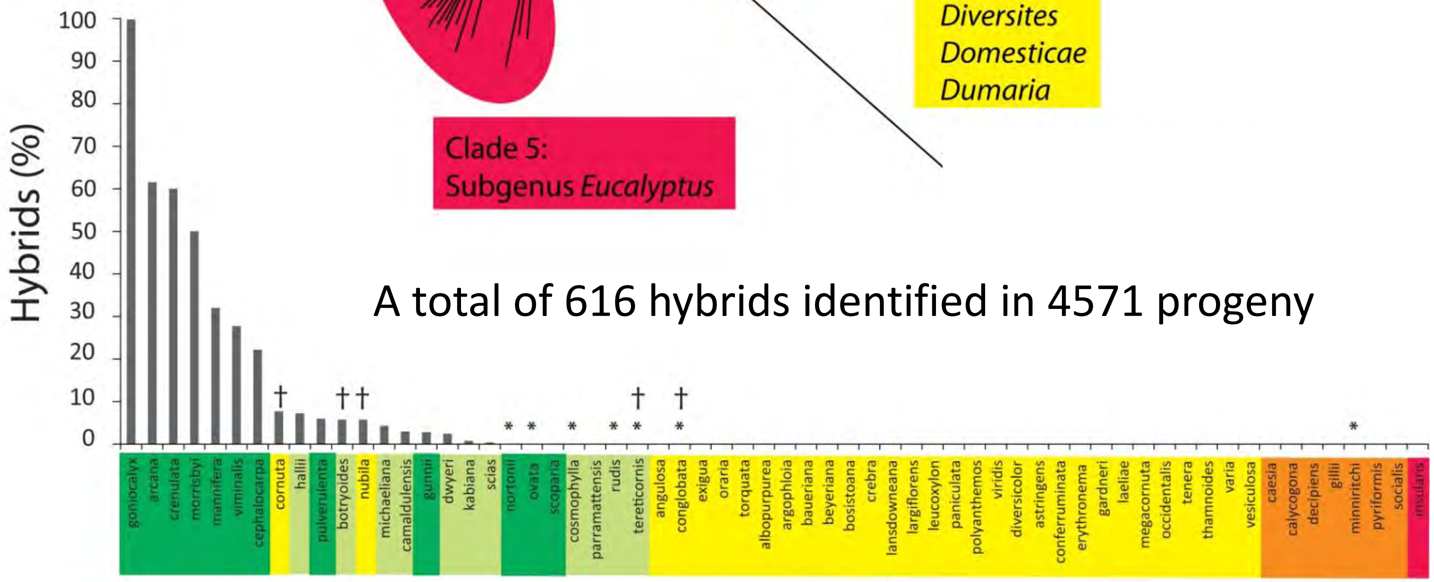




1. Hybrid success reflects phylogenetic relatedness

Hybridisation with *E. globulus* was more common among species from Clades 1 & 2 (22 spp.) than from Clades 3 & 4 (4 spp.)



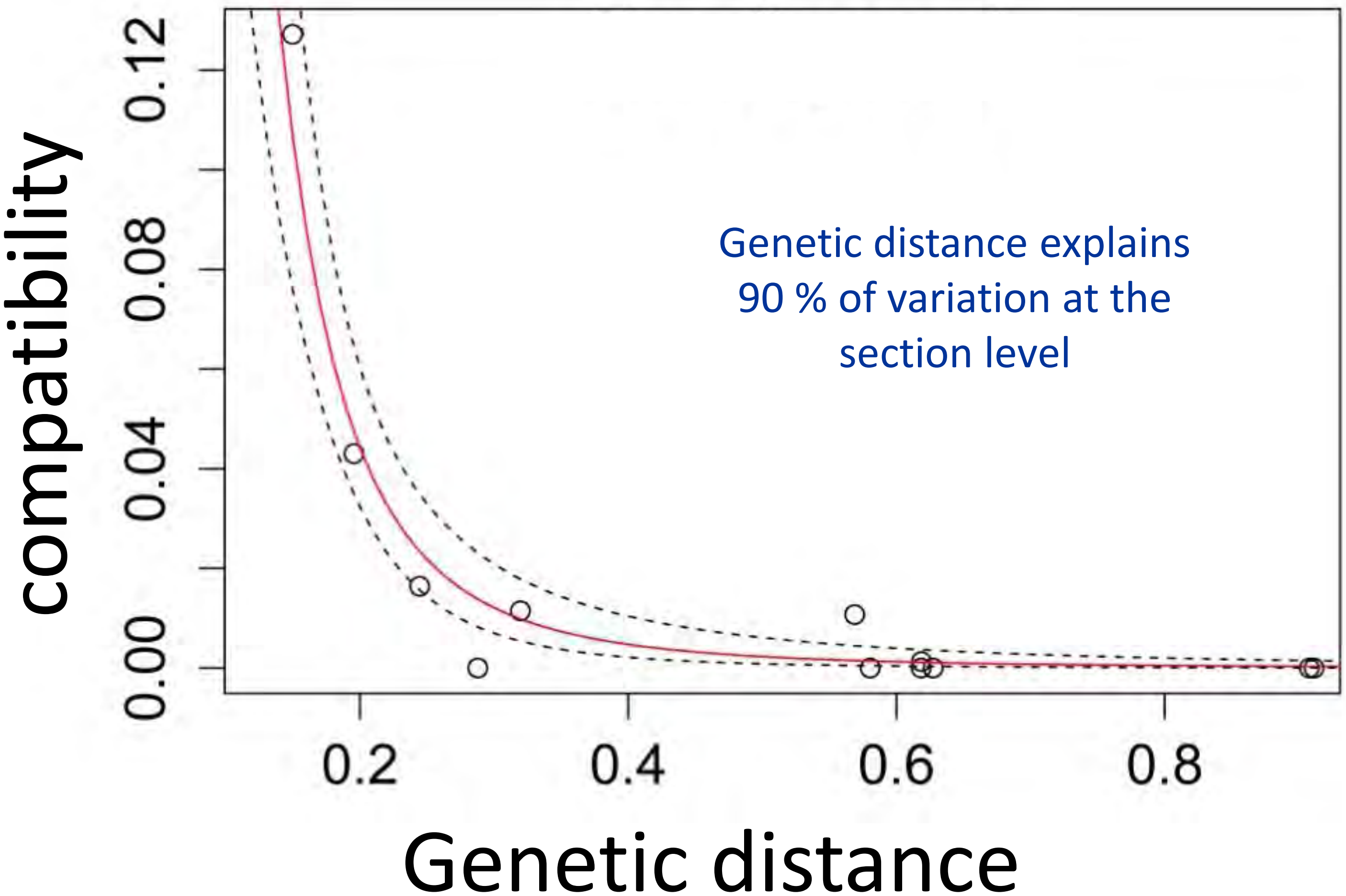


A total of 616 hybrids identified in 4571 progeny

* Hybrids from CS pollination only (not supplementary pollination)

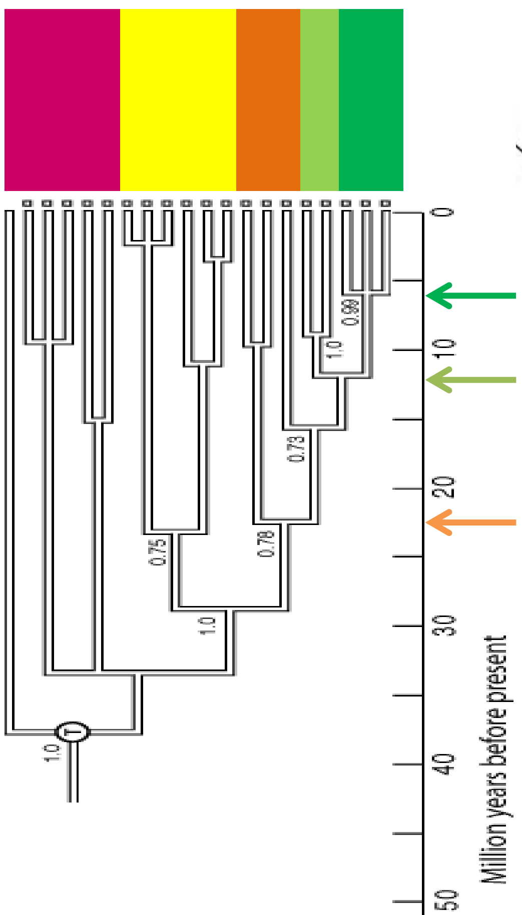
† Complete hybrid mortality

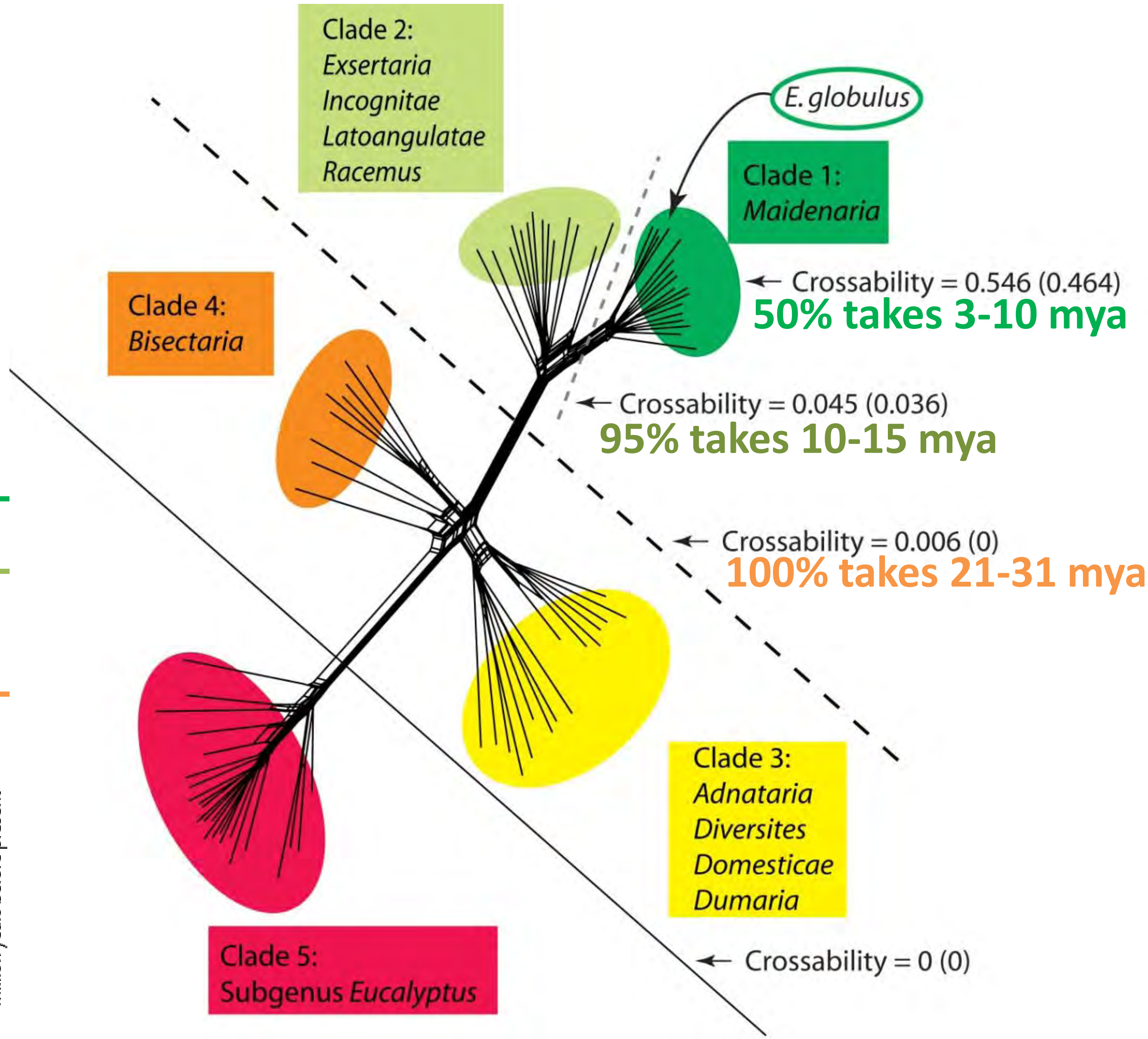
1. Compatibility declines as genetic distance increases



1. What is the time frame for reproductive isolation in *Eucalyptus*?

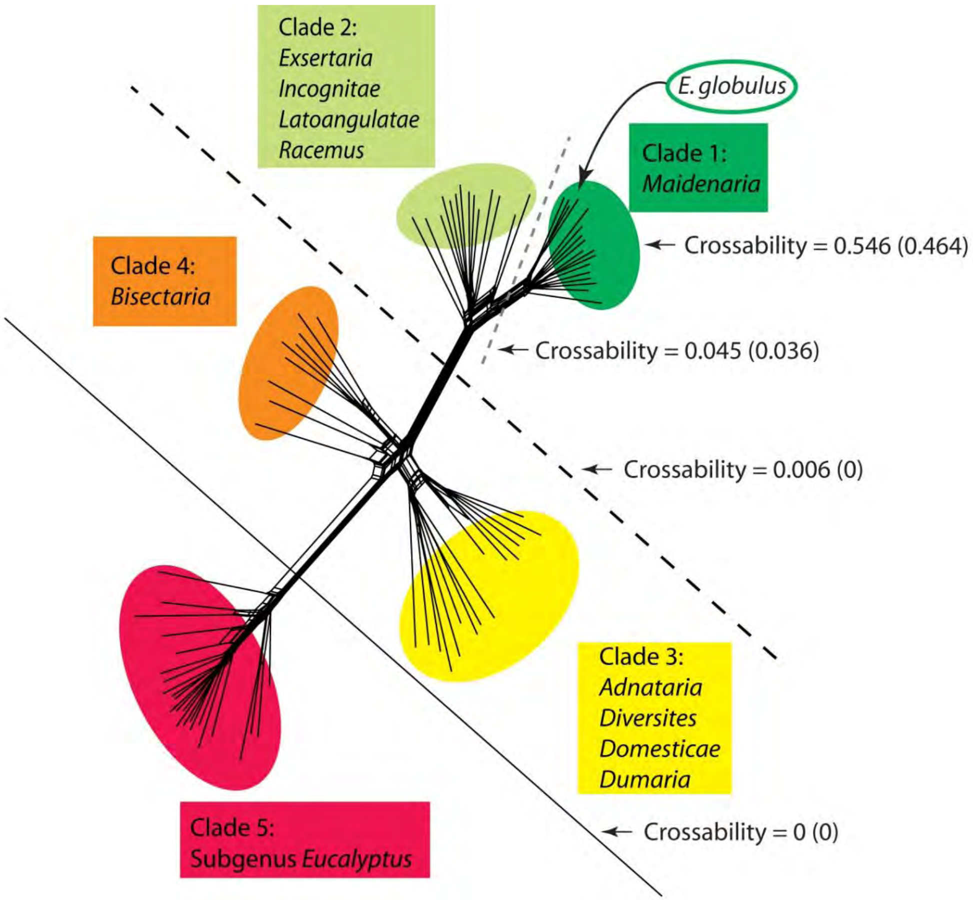
Dated eucalypt phylogeny (Crisp *et al.* 2011)





1. The risk of exotic gene flow from *E. globulus* plantations

- Previously 484 'at risk' species (within Subg. *Symphyomyrtus*)
- Clades 3 & 4 are isolated, leaving 138 'at risk' species
- The 70 species in Clade 2 have a 45% lower risk than the 68 species in clade 1



2. The case of *Eucalyptus ovata*

- known to hybridise with *E. globulus*
- hybrids have distinctive morphology
- widely distributed in the plantation zone
- common *E. globulus* plantation neighbour
- one of the most *at-risk* species (Barbour *et al.* 2008)

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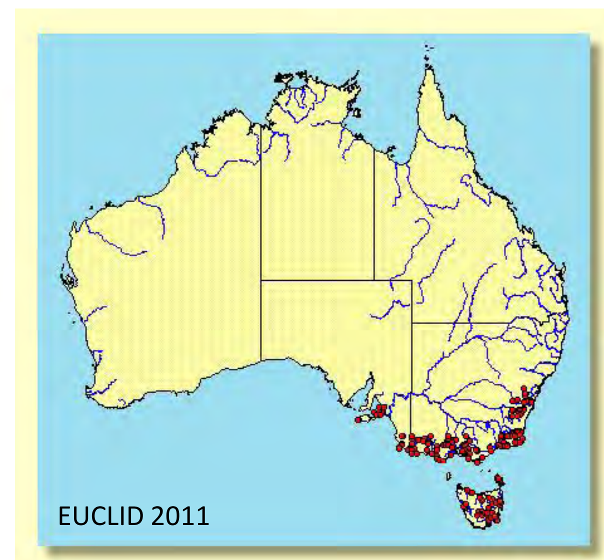
BIOLOGICAL CONSERVATION

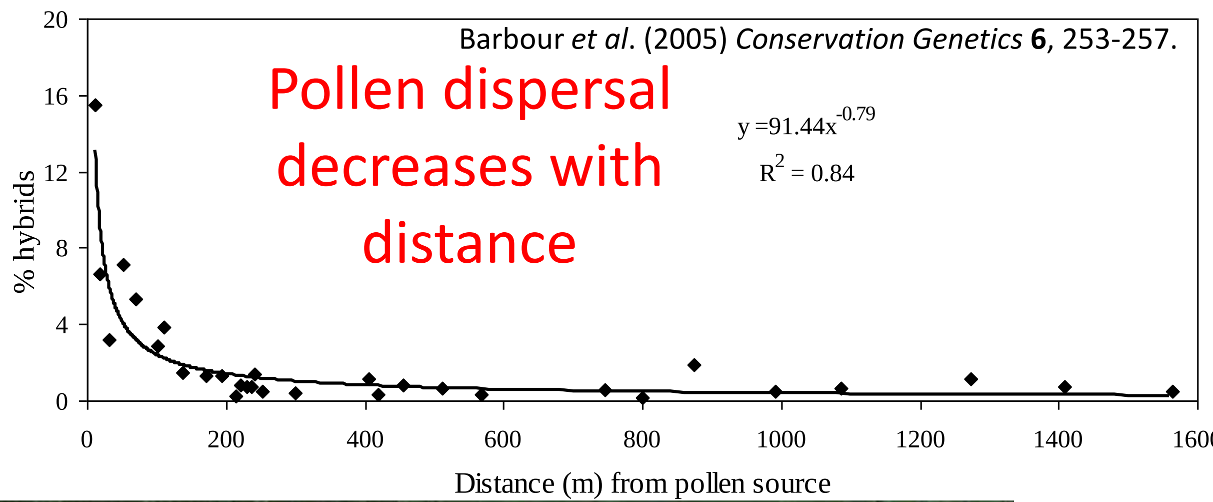
Assessing the risk of pollen-mediated gene flow from exotic *Eucalyptus globulus* plantations into native eucalypt populations of Australia

Robert C. Barbour, Yvonne Otahal, René E. Vaillancourt, Bradley M. Potts*



2.1: Landscape context: Does patch size affect hybridisation risk?

What is the effect of patch size in fragmented landscapes?



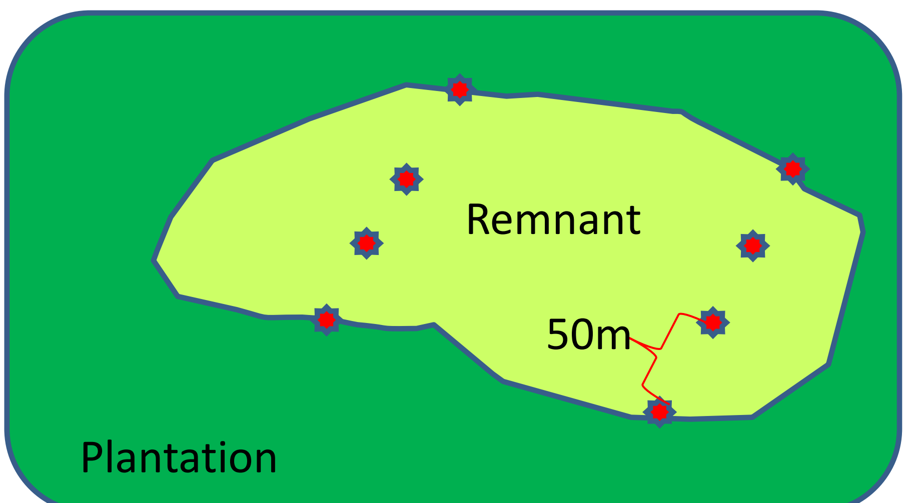
2.1: Does patch size affect hybridisation risk?

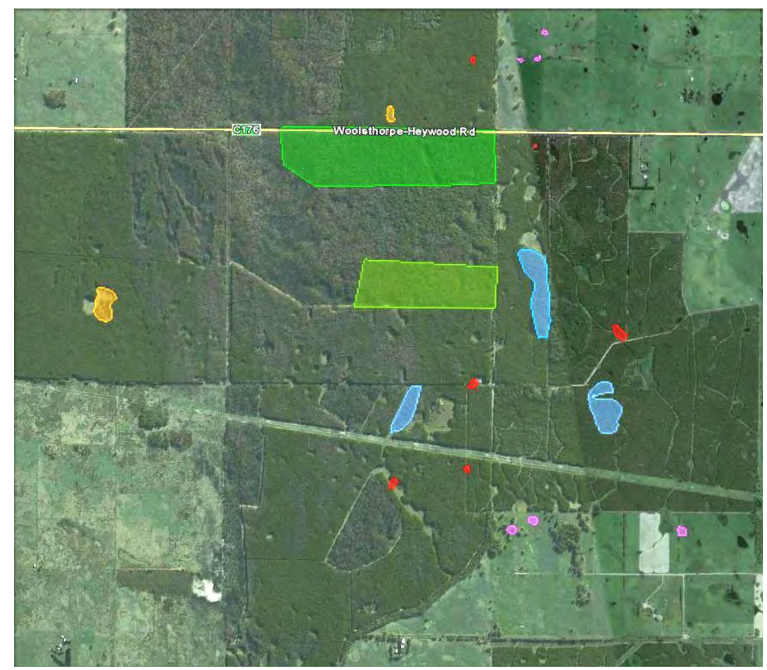
We identified five remnant categories:

1. isolated paddock tree 50 to 200m from plantation edge
2. 1-30 trees surrounded by plantation
3. ~50 trees surrounded by plantation
4. > 100 trees surrounded by plantation
5. > 100 trees continuous native forest adjoining plantation

Remnant category	*n* patches	*n* trees
1	14	14
2	10	32
3	5	32
4	4	32
5	4	32
Total	23	142

- open-pollinated seed collected from *E. ovata* in each remnant
- in categories 2, 3 and 4, trees were sampled on the boundary and 50m inside the remnant.
- capsule abundance assessed in the plantation



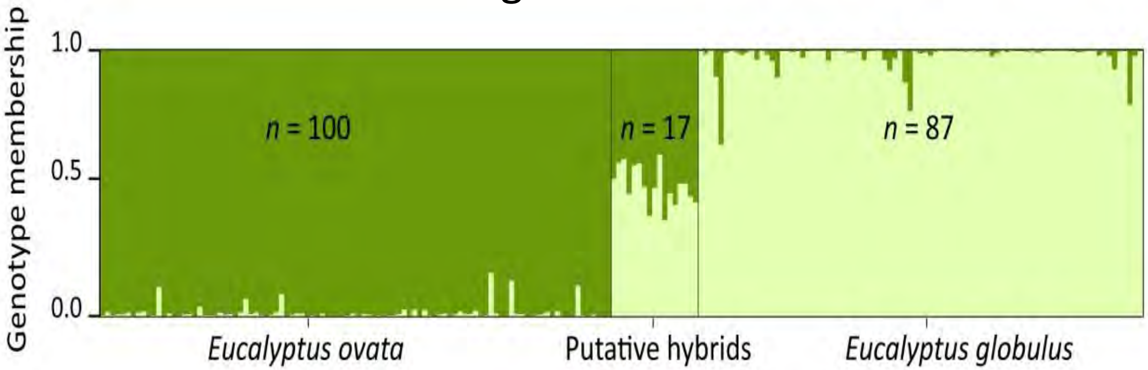


2.1: Does patch size affect hybridisation risk?

E. ovata

E. ovata x *globulus* F1

Hybrids identified from morphology, confirmed using molecular markers

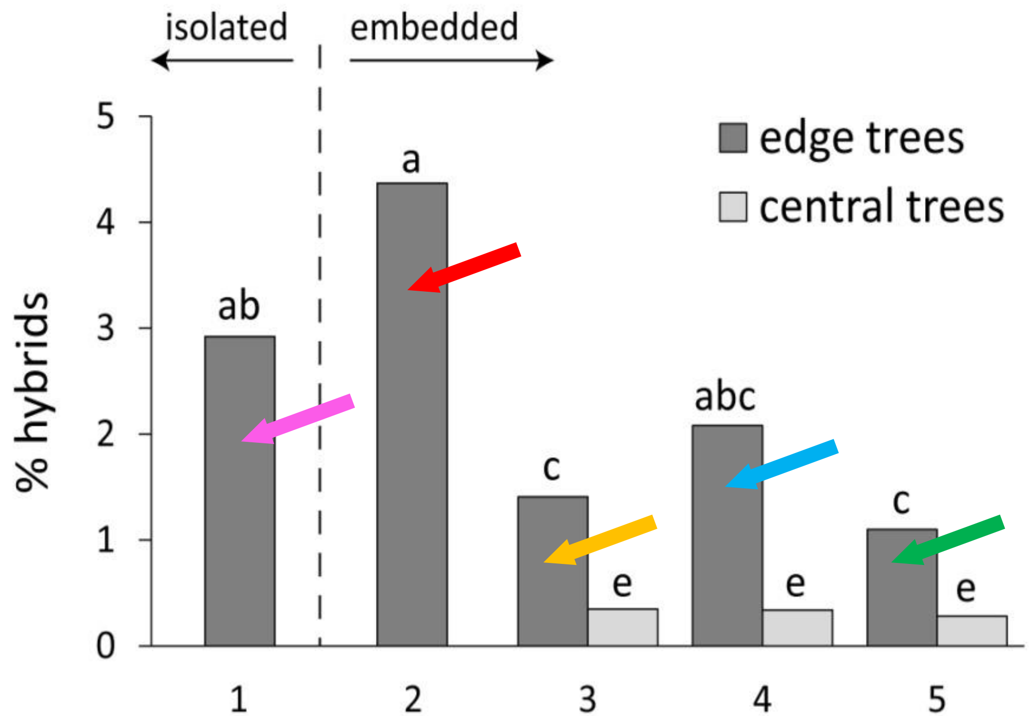


> 24,000 seedlings screened

1.62% exotic hybrids

2.1: Does patch size affect hybridisation risk?

(a) Exotic hybrids



- Patch size and tree position in the landscape effect hybridisation rate
- Minimising fragmentation and maximising embedded remnant size will help maintain genetic integrity

2.2: How frequent is hybrid establishment in the wild?

Targeting high risk sites, because:

- Rare events are hard to survey for
- Obtain a conservative estimate i.e. worst case scenario

Conditions:

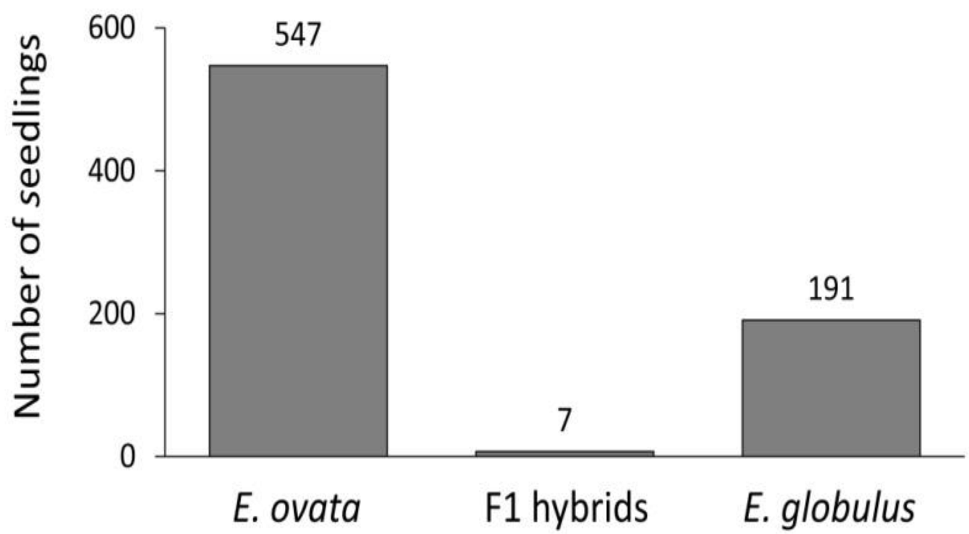
- *E. globulus* plantation beside *E. ovata* native forest with no native *E. globulus*
- Recruitment from *E. ovata* and plantation *E. globulus* of equivalent age

Method

- Categorise every seedling (out to 20m) as pure *E. ovata,* pure E. globulus, or *E. ovata* x globulus hybrid

2.2: How frequent is hybrid establishment in the wild?

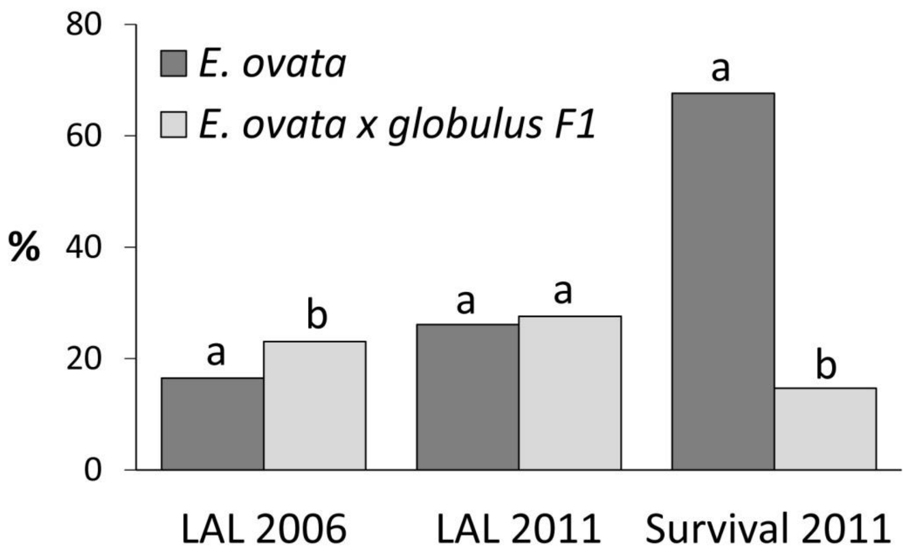
- 216 km of plantation edge surveyed in Tasmania, Gippsland and the green triangle
- Only 4 high-risk sites identified
- 12ha surveyed in detail along 4 km of plantation native forest boundary



2.3: Will hybrids survive in the wild?

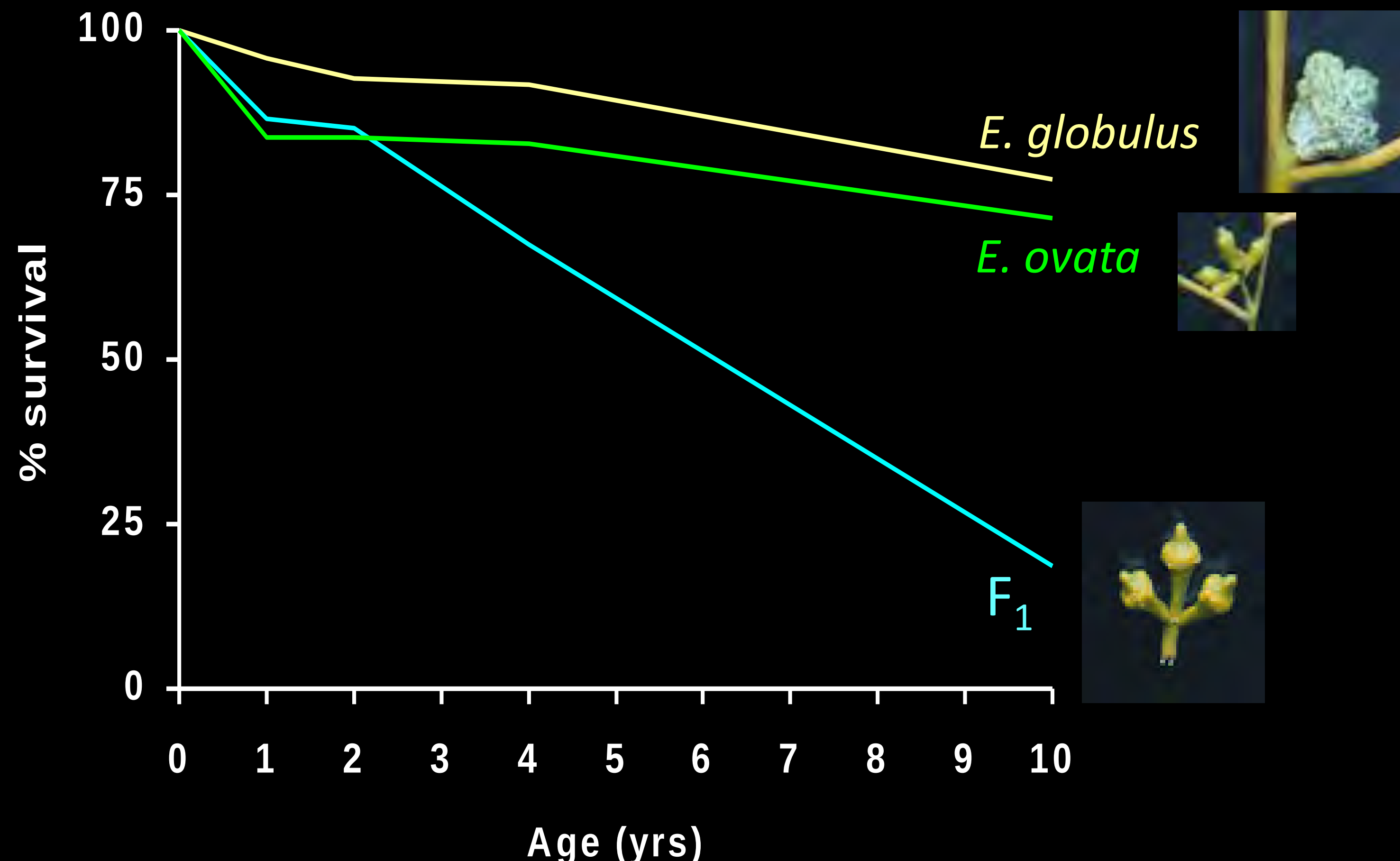
In 2006 Robert Barbour paired 80 naturally establishing *E. globulus* x *ovata* hybrids with 80 p *E. ovata* (Barbour *et al*. 2008).

- In 2010 I found 33 pairs
- 23 pure and 5 hybrids (P<0.001)
- The hybrids are 78% less fit than the pure seedlings



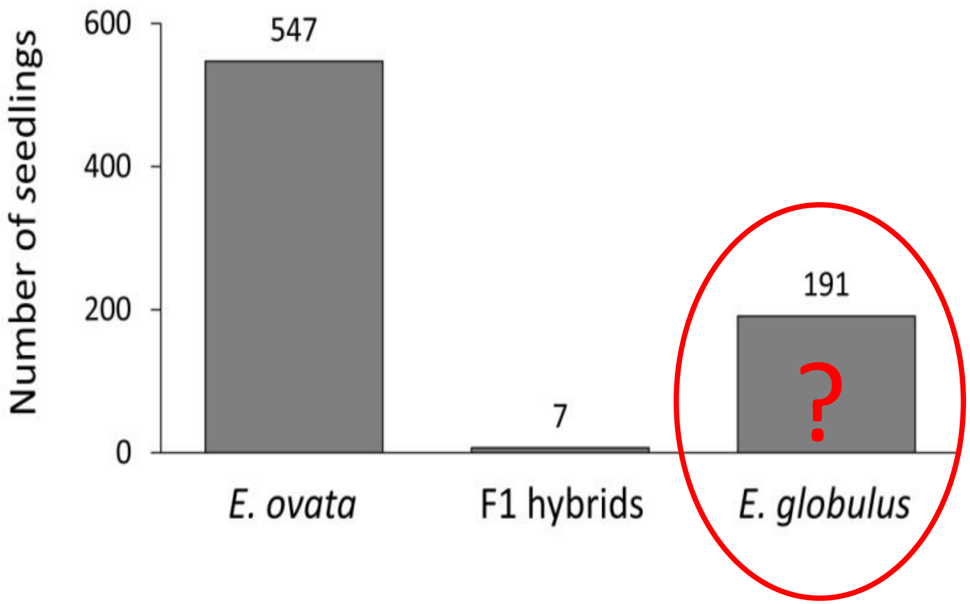
2.3: Will hybrids survive in the wild?

Similar results were obtained by Lopez *et al.* (2000) in a trail situation using hybrids from controlled crosses, hybrids also flowered asynchronously = secondary barrier



Lopez *et al.* 2000, *Heredity*, **85**, 242-250

3: What about the wildlings?



Plantations are cyclical:

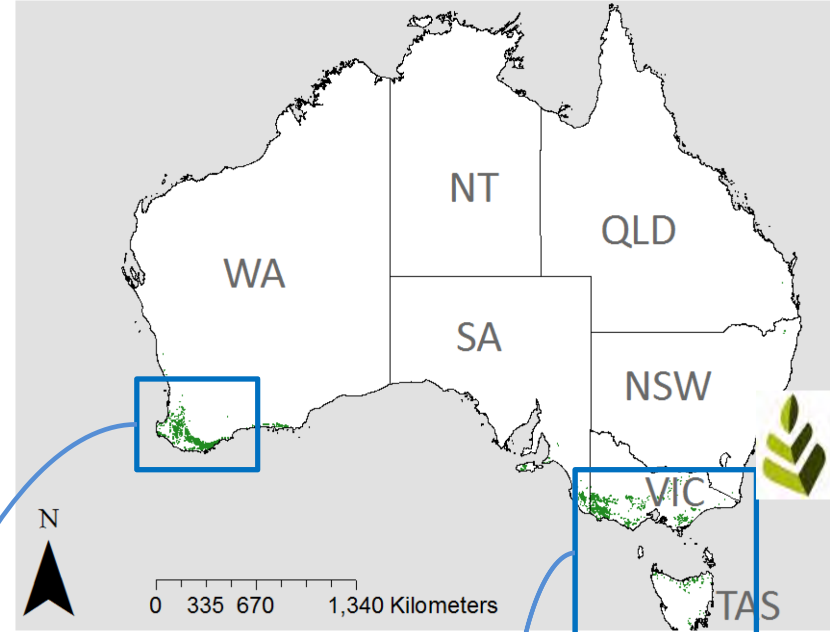
plant – grow – flower – harvest – plant?

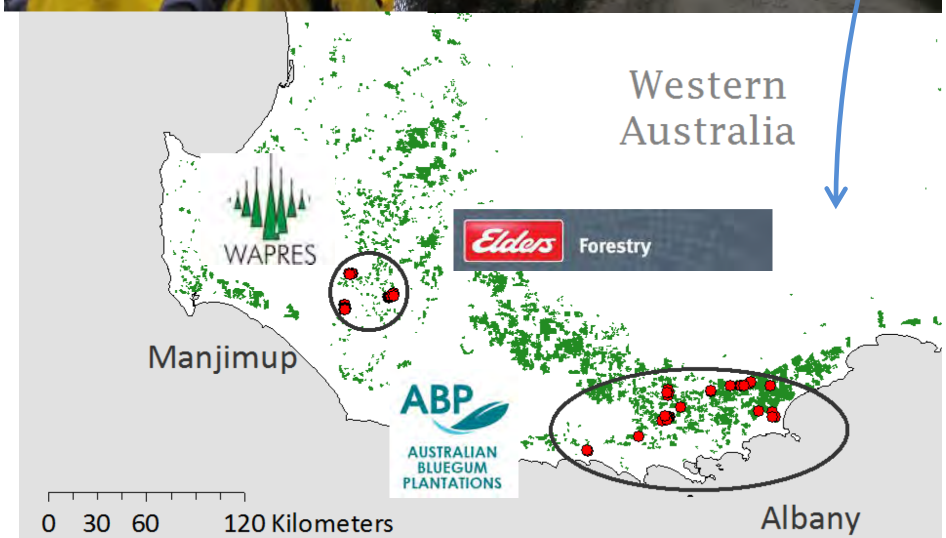
Yr1 Yr6 Yr12

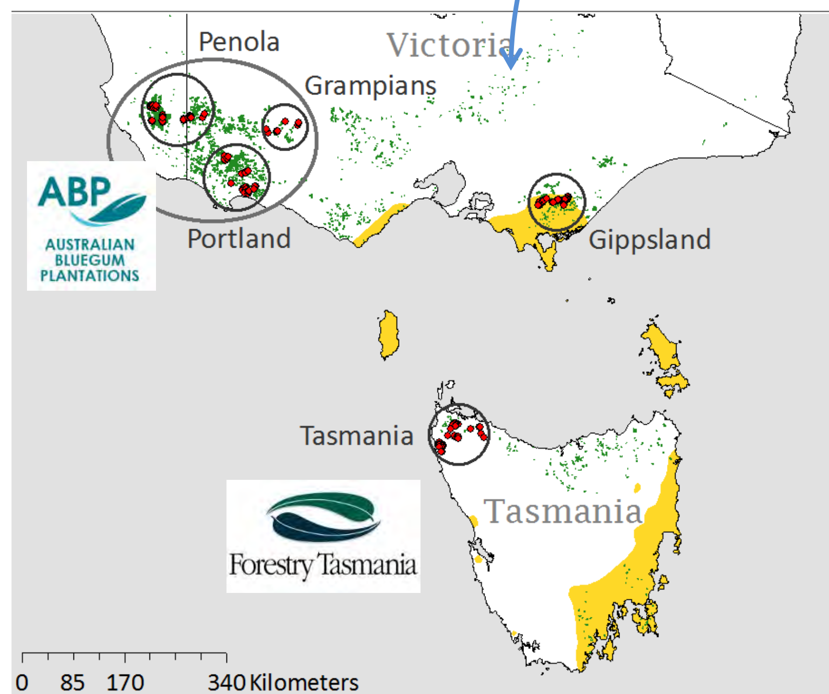
538,000 ha now, but what will be replanted?

Wildling establishment => weeds, and a long term exotic pollen source => long term exotic gene flow?

3: How common is wildling establishment and what factors control it?







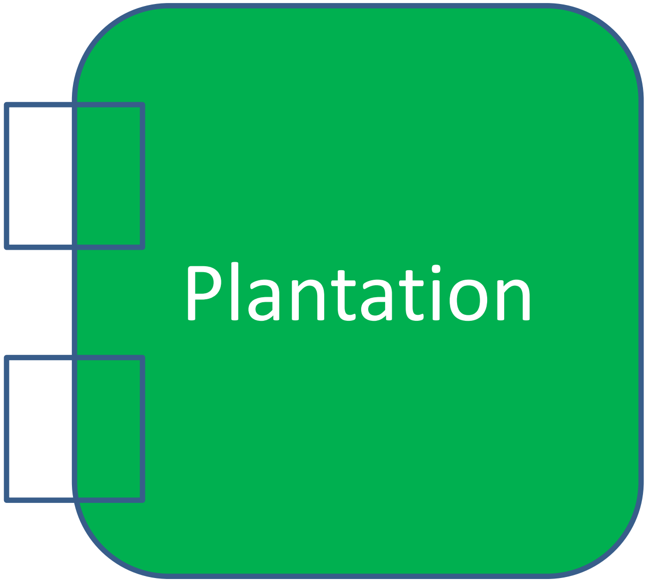
3: A survey at two geographic scales

1. broad scale survey:

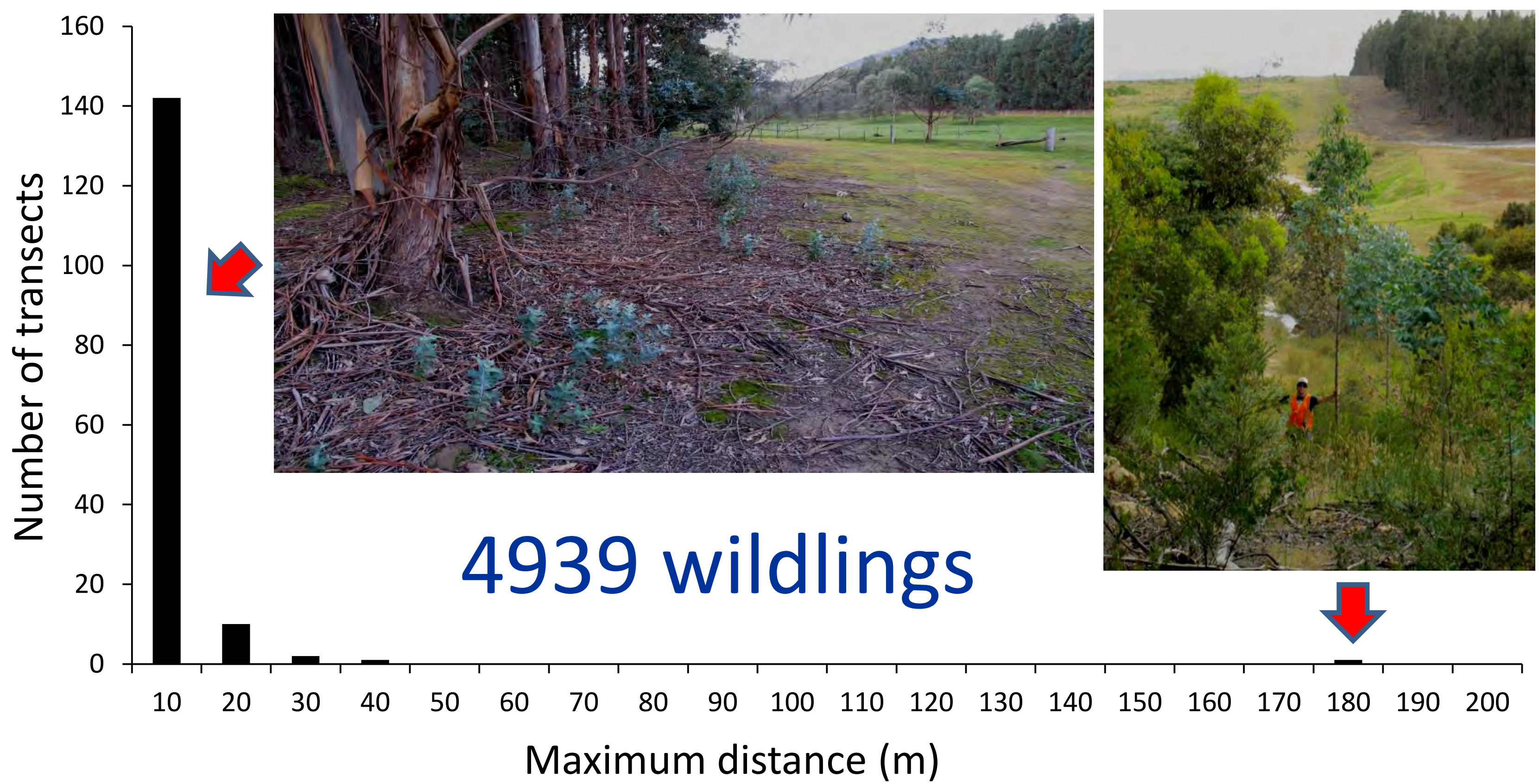
- Surveyed 269 plantation boundaries (290km)
- Across all main growing regions
- To investigate regional and bioclimatic factors

2. fine-scale survey:

- Density trigged paired plots
- Local and microsite factors



3: Seedlings mainly established within 10m of the plantation edge

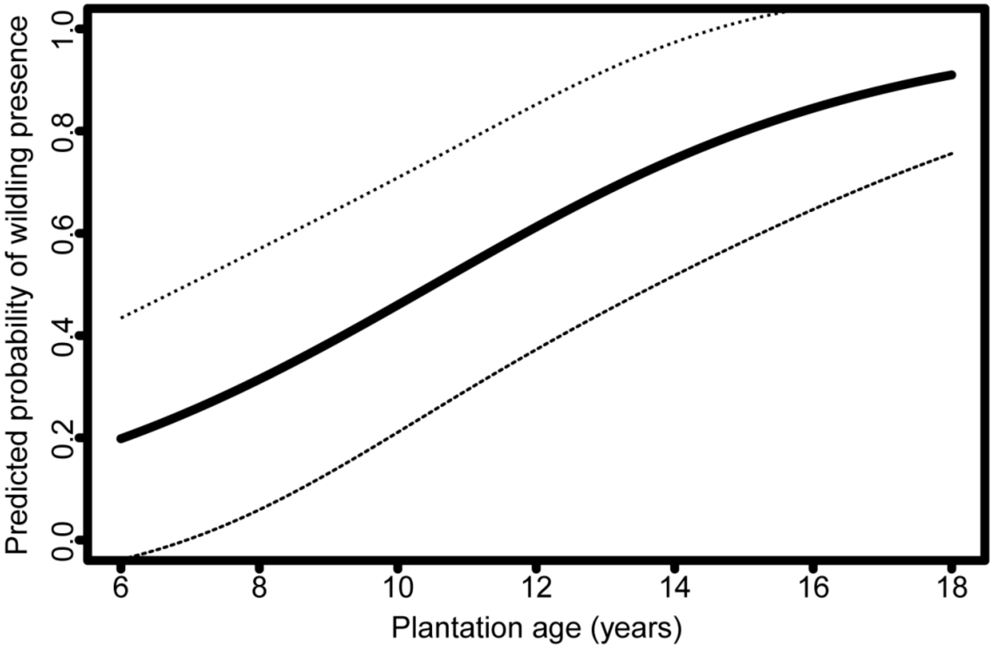


3: Regional variation

Region	No. transects surveyed	Distance surveyed (km)	Total No. wildlings	No. wildlings/km	No. fine-scale pairs
Albany	31	56.1	1274	**22.7**	22
Manjimup	33	21.5	851	**39.6**	9
Grampians	19	17.2	624	**36.3**	5
Penola	49	64.2	75	**1.2**	3
Portland	40	44.5	1483	**33.3**	20
Gippsland	59	60.4	525	**8.7**	12
Tasmania	38	26.5	107	**4.0**	0
Total	269	290.4	**4939**	**17.0 (8/ha)**	71

We then used a modelling approach to determine factors driving the variation

3: Wildlings increase with plantation age



Variable	df	χ^2	*p*
Transect length	1	3.82	0.0507
Region	6	44.87	0.0001
Plantation age	1	13.69	0.0002
Precipitation seasonality	1	3.61	0.0576
Region * Precipitation seasonality	6	32.32	0.0001

total variation exp. = 30%

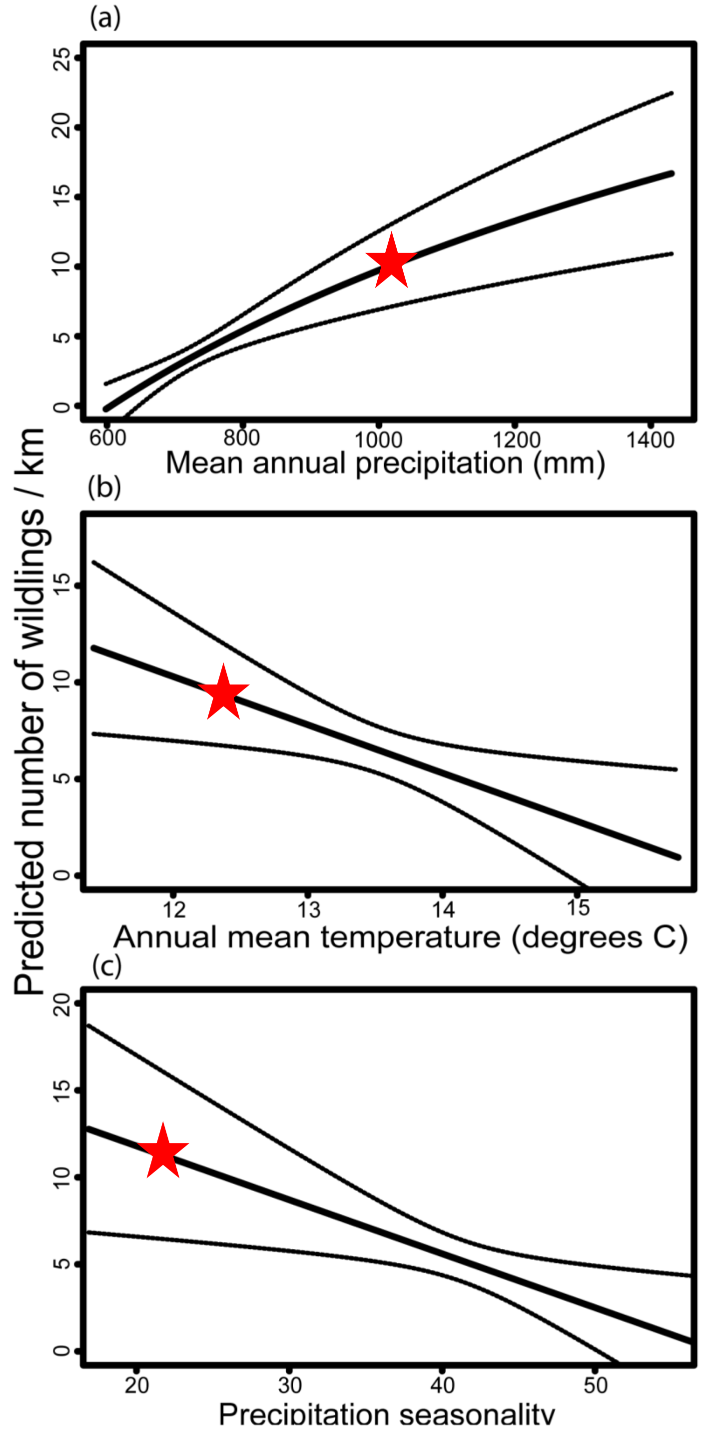
Typical rotation age is 10 -15 years

3: Climatic conditions similar to native range seem to promote establishment

- regular rainfall
- high rainfall
- low temperature

Variable	df	χ^2	*p*
Transect length	1	1.9	0.1691
Region	6	56.7	<0.0001
Plantation age	1	4.9	0.0264
Annual mean temperature	1	10.9	0.0009
Precipitation seasonality	1	10.1	0.0015
Annual precipitation (log)	1	22.3	<0.0001
Region * Plantation age	6	24.3	0.0005

total deviance exp. = 44.8



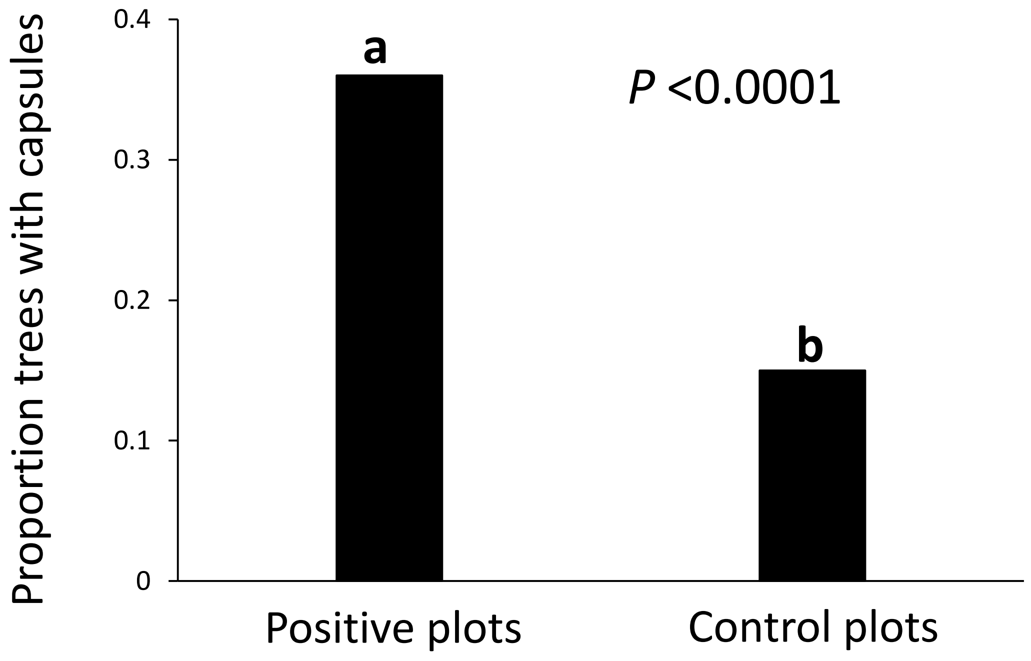
3: Fire promotes establishment

3: How common is wildling establishment and what factors control it?

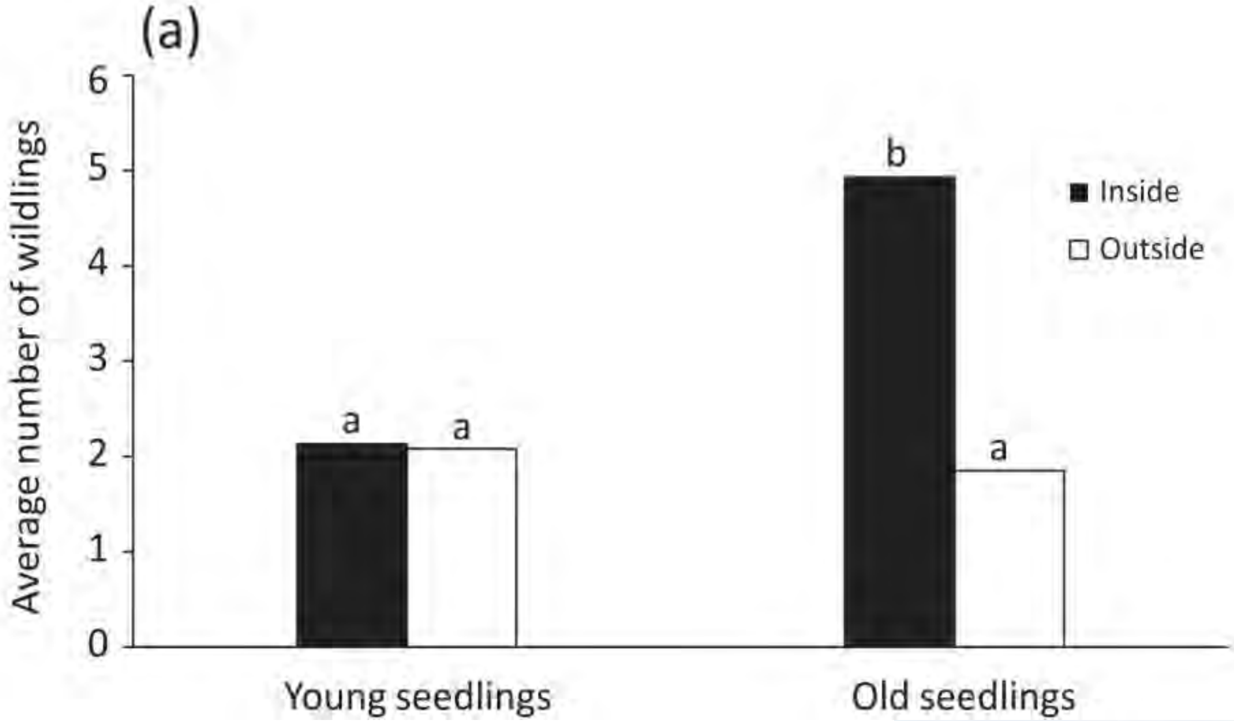
2. fine scale survey results:

- None triggered in Tasmania

	Gippsland	Grampians	Penola	Portland	Manjimup	Albany	Total
Number of plots (pairs)	12	5	1	22	9	22	71
Number of wildlings /plot	9.8	9.8	6	8.4	9.8	6.7	9



Topography; aspect; ground cover classes; disturbance were all non-significant

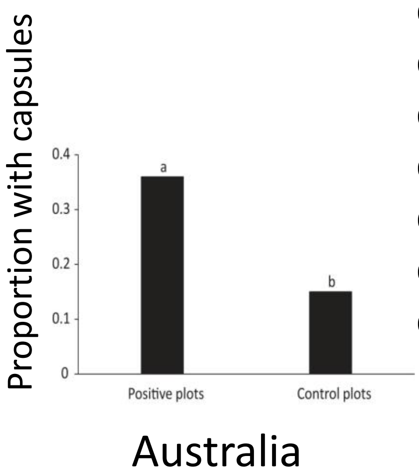


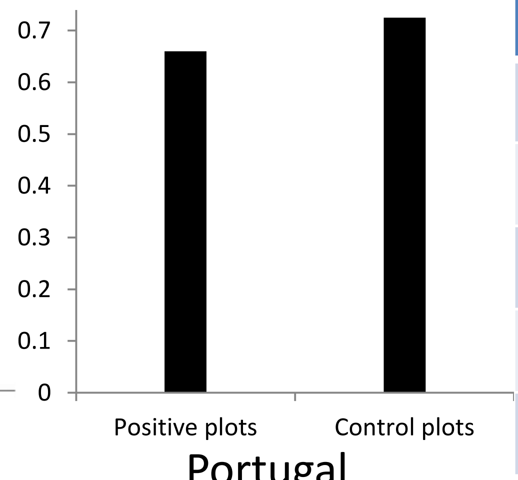
3: How common is wildling establishment and what factors control it?

Fire break management could be helping control the spread of wildlings

3: But we need to keep monitoring...

In Australia 12% of 2nd rotation
In Portugal 80% 2nd or older

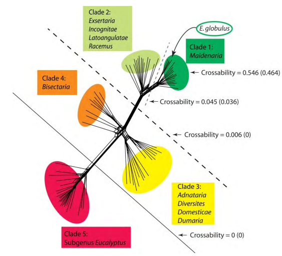




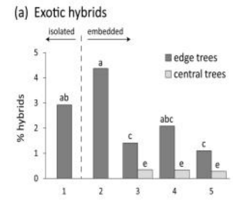
	Australia	Portugal
Km surveyed	290	33
Wildlings/km	17	245
Transects	269	96
FS positive plots	71	68
FS control plots	71	22*

Main conclusions

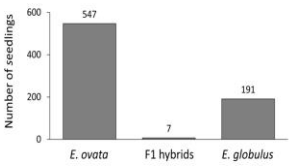
1. Genetic barriers to hybridisation exist within *Symphyomyrtus* reducing the number of species at risk by 71%; main threat to *Maidenaria*



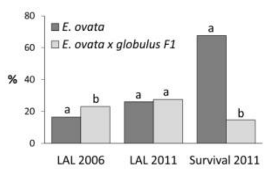
2. Patch size and tree position affect hybridisation; maximising remnant size will help maintain genetic integrity



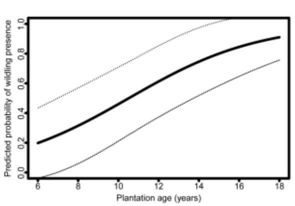
3. Hybrid establishment in the wild is low



4. Hybrid survival in the wild is 78% lower than pure native seedlings



5. Wildling establish is relatively low, and associated with older plantations and high reproductive output



What do the results mean for managing exotic gene flow

1. The barriers to exotic gene flow identified in this project indicate that the genetic risk posed by *E. globulus* plantations is low and will mainly be a concern where:
   1. Species are closely related to *E. globulus*
   2. They occur in small fragmented population/patches
   3. And/or are of conservation significance
2. Wildlings do not currently seem to pose a major risk in managed plantation estates, but the experience in older estates in Portugal shows that continued monitoring is warranted, particularly if current management changes

Future issues: will exotic gene flow be a problem if assisted migration becomes a reality?

Conservation and Policy

A Framework for Debate of Assisted Migration in an Era of Climate Change

JASON S. McLACHLAN,*†‡ JESSICA J. HELLMANN,† AND MARK W. SCHWARTZ*
*Department of Environmental Science and Policy, University of California Davis, California, CA 95616, U.S.A.
†Department of Biological Sciences, University of Notre Dame, Notre Dame, IN 46556, U.S.A.

Opinion

Cell PRESS

Assisted colonization is not a viable conservation strategy

Anthony Ricciardi[1] and Daniel Simberloff[2]
[1]Redpath Museum, McGill University, 859 Sherbrooke Street West, Montreal, QC H3A 2K6, Canada
[2]Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996, USA

What is now considered a risk may be of little concern, or even a target of conservation programs, if assisted migration becomes widespread

Is Australia ready for assisted colonization? Policy changes required to facilitate translocations under climate change

ANDREW A BURBIDGE[1A], MARGARET BYRNE[2], DAVID COATES[2], STEPHEN T GARNETT[3], STEPHEN HARRIS[4], MATT W HAYWARD[5], TARA G MARTIN[6,7] EVE MCDONALD-MADDEN[6,7] NICOLA J MITCHELL[8], SIMON NALLY[9] and SAMANTHA A. SETTERFIELD[10]

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