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Myrtle Rust (*Austropuccinia psidii*) poses unprecedented challenges for plant conservation and recovery

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Say hello (and goodbye?) to *Lenwebbia* sp. 'Main Range' (P.R. Sharpe+ 4877) -- likely to become the first Myrtle Rust-mediated extinction in Australia

Cloud-forest endemic, naturally low numbers. McPherson and Main Ranges, NSW/SE Qld
Known for about 10 years in Queensland; only in 2018 recognised as occurring just on NSW side of the border

- Left: Healthy flowering plant, Lamington NP, Qld, 2004 (Robert Price).
- Centre: After Myrtle Rust attack, Lamington NP, March 2018 (Lui Weber).
- Top right: In habitat, McPherson Range (Robert Price)
- Lower right: Cuttings at Mount Annan Botanic Garden, March 2018 (RO Makinson).

Just listed (9th Nov.) in NSW as Critically Endangered

Myrtle Rust – *Impacts Review*, and *Draft Action Plan*

- **Makinson RO (2018) Myrtle Rust in Australia – a draft Action Plan. Plant Biosecurity Cooperative Research Centre, Canberra**. http://www.pbcrc.com.au/?s=Myrtle+Rust
  This is a condensed framework for what needs to be done on the environmental side of the Myrtle Rust problem, coming out of a year-long synthesis and consultative process.

- **Makinson RO (2018) Myrtle Rust reviewed: the impacts of the invasive pathogen *Austropuccinia psidii* on the Australian environment. Plant Biosecurity Cooperative Research Centre, Canberra**. http://www.pbcrc.com.au/?s=Myrtle+Rust This provides the evidentiary basis for the above Draft Action Plan – synthesis of knowledge up to June 2018, including revised Australian host list and recommendations for a nationally coordinated conservation response.

- Co-funded by *Plant Biosecurity CRC* and *NESP* (Comm. Dept of Environment)
- Both documents soon to be available on ANPC website (‘Resources’ sub-page), as part of a full revamp of the Myrtle Rust content.

Impacts to date

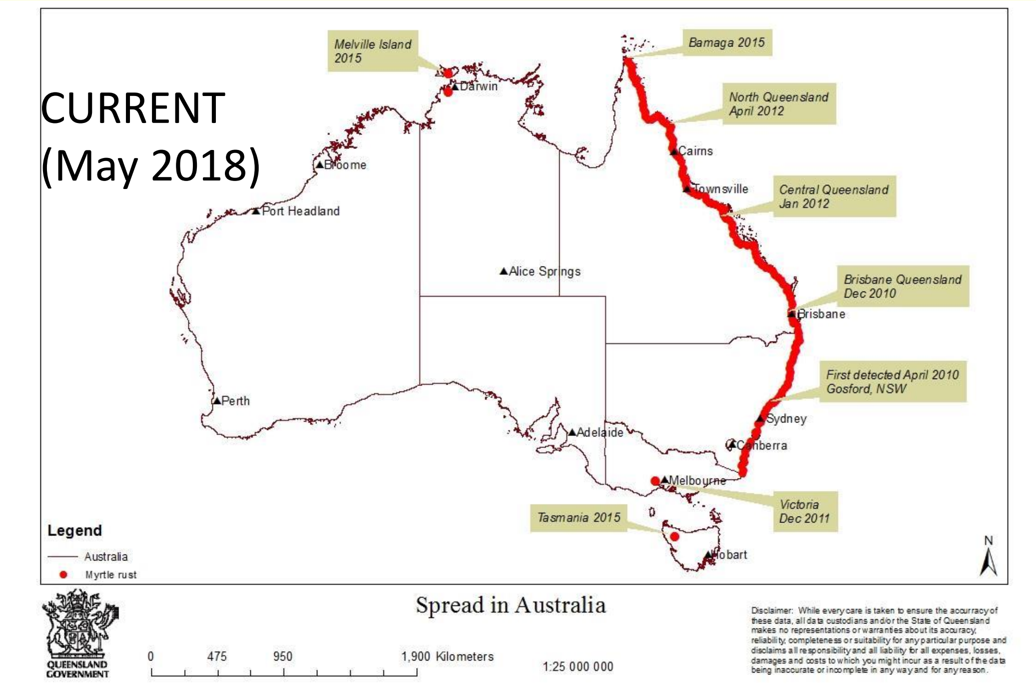
Since 2010:

- One ‘pandemic’ strain of *A. psidii* naturalised in Australia and the wider region,
- 358 Australian native host species to date (16% of native Myrtaceae).
- 4 species approaching rapid extinction as direct result of Myrtle Rust disease.
- 41 more species known or suspected in serious decline; some ecosystems at risk.
- Only c. 3% of screened Australian Myrtaceae have <u>failed</u> to become infected.
- Host range will increase for this strain alone – with or without spread to WA.
- Many hosts exposed over their entire range – no refugia (windborne spores).

Future considerations:

- Incremental declines in lower-susceptibility species (or at critical life stages).
- Ecosystem-level declines (already in temp. rainforest; potential in *Melaleuca* wetlands).
- Pandemic strain thought to be clonal (but limited studies to date) – evolutionary potential uncertain
- No consistent monitoring for detection of mutation, sexual evolution, or impacts.
- **Other strains of same pathogen in S. America and S. Africa – two with particular affinities for eucalypts.**

Austropuccinia psidii ‘pandemic strain’ in Australia – geographic range



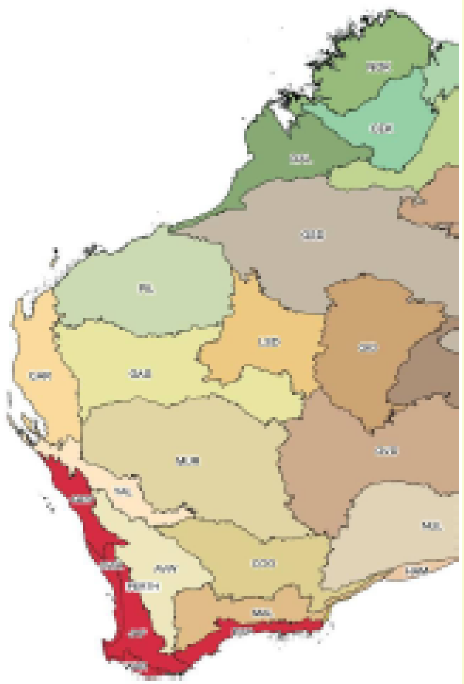
Myrtaceae in Western Australia

2253 native Myrtacae species in Australia.

1568 native Myrtaceae species in W.A.

1043 of the WA species are in just 5 south-west IBRA Bioregions:

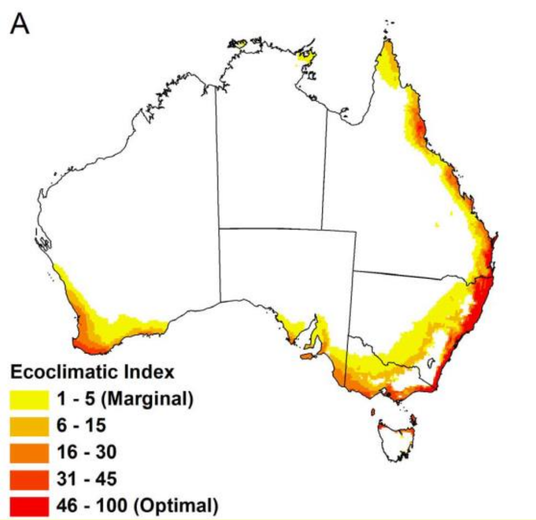
502	Geraldton Sandplain
378	Swan Coastal Plain
449	Jarrah Forest
154	Warren
548	Esperance Plain

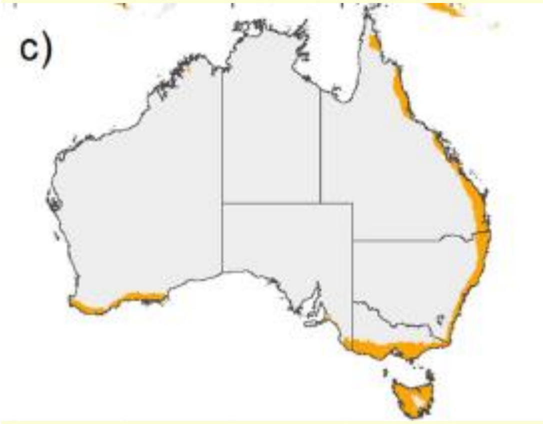


Top: IBRA v7 Bioregions (red = 1043 species of Myrtaceae).

Lower: SW WA detail from Kriticos et al. (2013): Ecoclimatic area suitable for Myrtle Rust.

Flora statistics courtesy K. Thiele, WA Herbarium, May 2013.





LL: CLIMEX suitability map, Kriticos et al. (2013)

LC: MAXENT suitability map (current climate), Berthon et al. (2018)

A conservation response is feasible …

…. but requires a level of national coordination and investment rarely seen for environmental threats (although common enough for agricultural pathogens).

Draft Action Plan elements:

Establish momentum, funding and leadership for a coordinated national environmental response

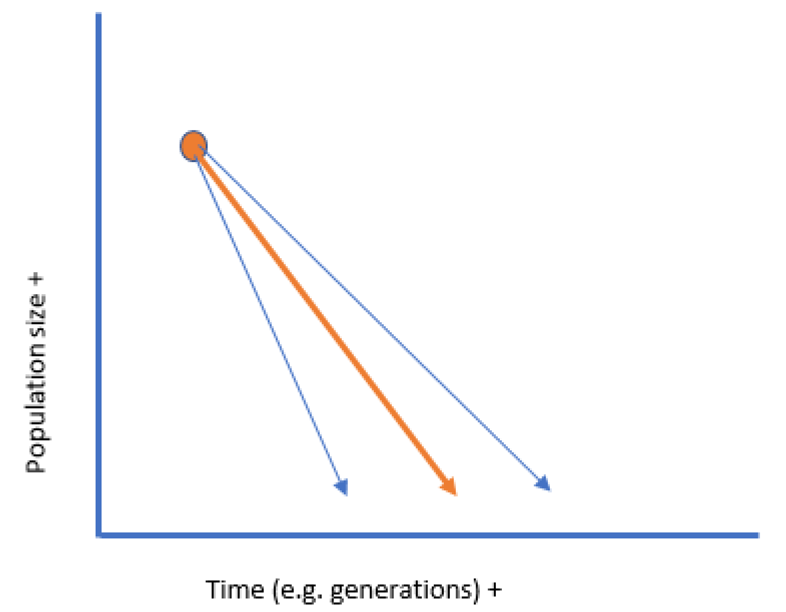
- Theme 1: Enabling the response: Establish leadership, resourcing, coordination (national).
- Theme 2: Awareness & engagement: General and key expertise & stakeholders, incl. Indigenous.

Adopt a coordinated and long-term national environmental response

- Theme 3: Impact assessment: Info flow; standardised monitoring; rapid surveys; quantified impact studies.
- Theme 4: Towards recovery: Germplasm capture and storage-enablement; assess & species resistance traits; Explore breeding, reinforcement & reintroduction strategies for wild populations
- Theme 5: Biosecurity: Prevent arrival of new strains of *A. psidii in Indo-Pacific region*; Maintain domestic quarantine for WA and SA; Monitor for changes in pathogen population.

Priority species list

Scenario 1: Steep uniform decline



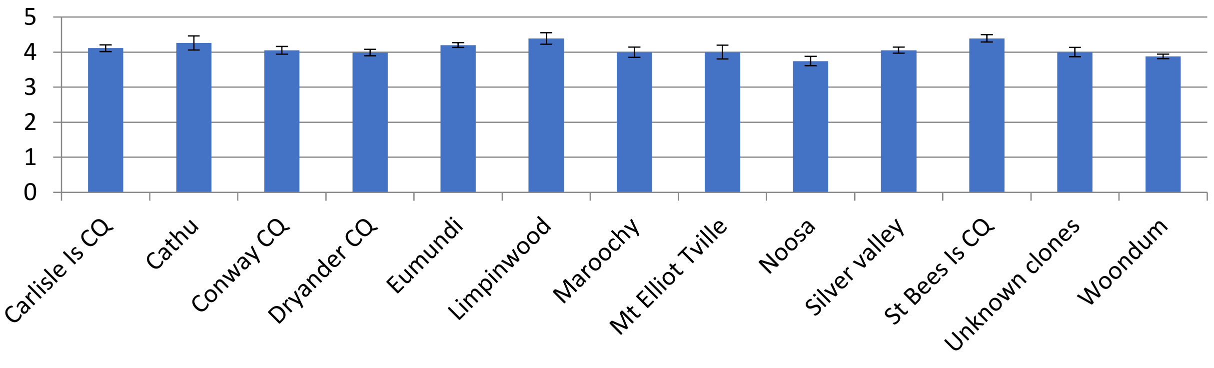
Uniform extreme susceptibility, no tolerant genotypes, high rate of decline:

- *Lenwebbia* sp. 'Main Range'
- *Rhodomyrtus psidioides* (photo lower left, K. Kupsch)
- *Rhodamnia rubescens*
- *Backhousia citriodora?*

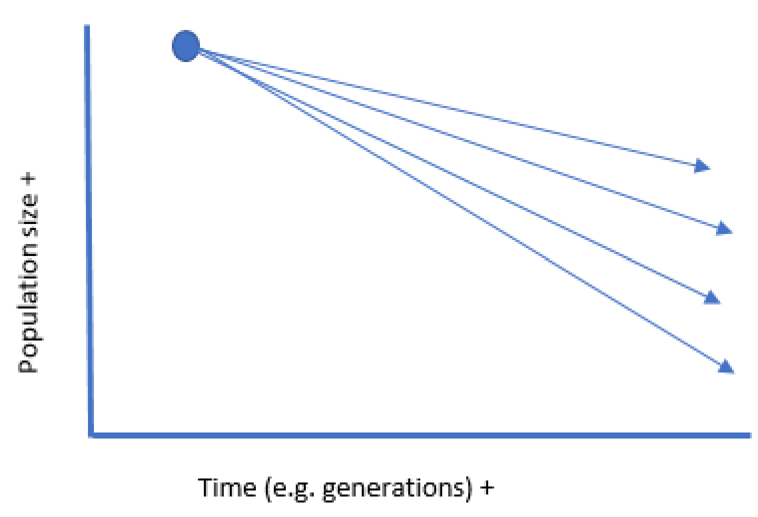
'Management' options:

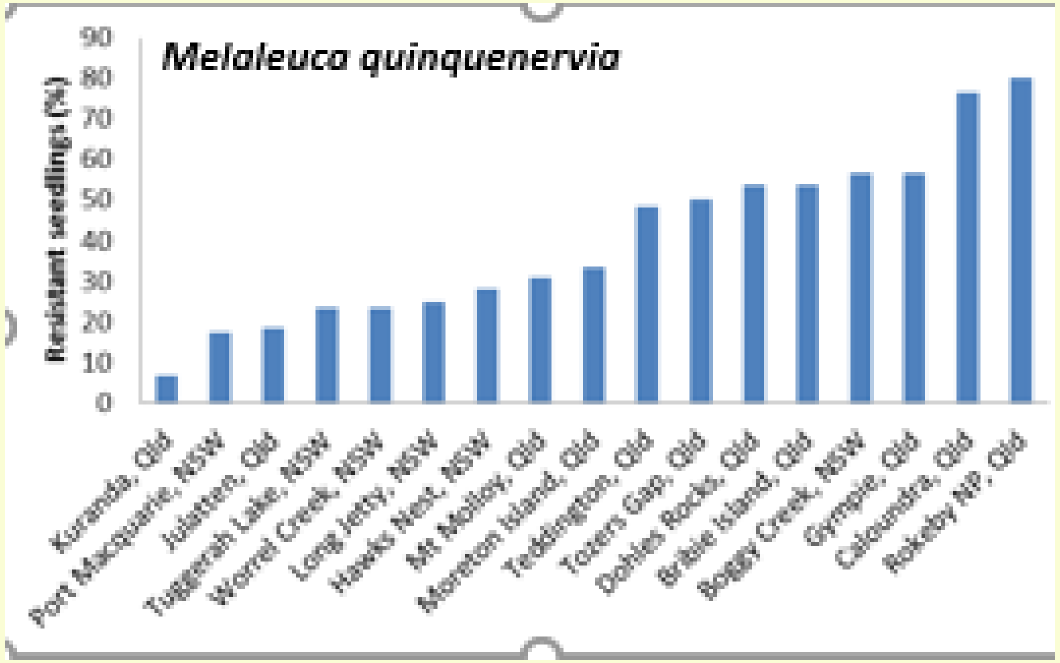
- **Germplasm salvage, ex situ conservation**
- **Transgenic breeding (or engineering) for resistance traits**

Backhousia citriodora **(Lemon Myrtle)** – modified from unpublished data courtesy G. Pegg and E. Lancaster : **Severity of myrtle rust infection (1—5) following inoculation with average standard errors or difference**



Scenario 2: **Moderate to severe decline,** variable between and within populations





Melaleuca quinquenervia, unpublished data courtesy G.S. Pegg (QDAF)

Variable susceptibility (high to extreme), some tolerant genotypes, variable rate of decline on population level – e.g.:

- *Melaleuca quinquenervia*
- *Melaleuca leucadendra ?*
- *Melaleuca viridiflora ?*

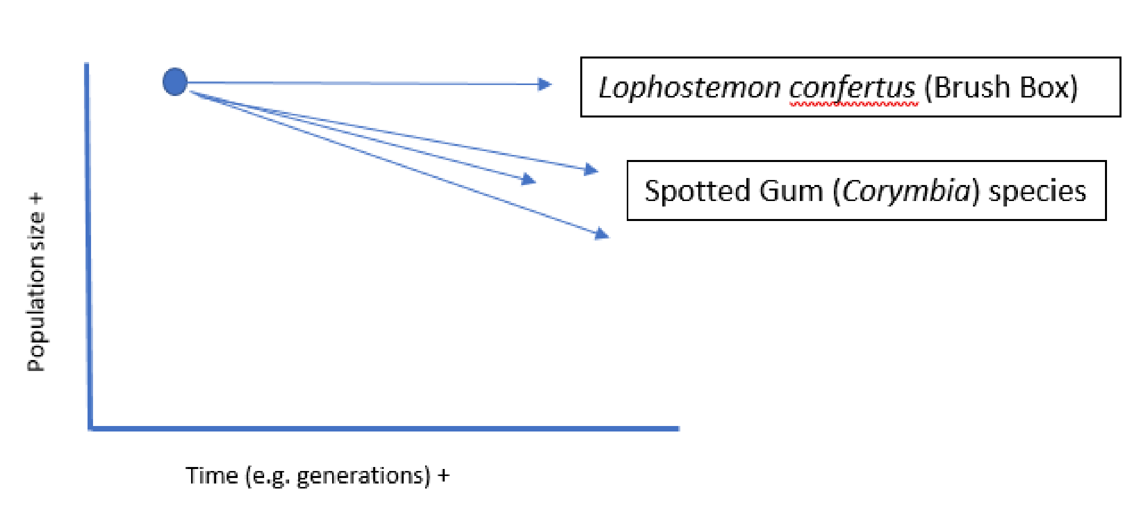
Mel. quin., P. Entwistle 2011

Management options:

- **Germplasm capture (enabling quantities)**
- **Track declines; track natural selection for resistance**
- **Translocation (augmentation) with resistant natural genotypes**
- **Rely on natural selection in other cases – but decline risk**

Scenarios 3, 4: Zero, or low to moderate decline

Adapted from unpublished data courtesy G.S. Pegg (QDAF)



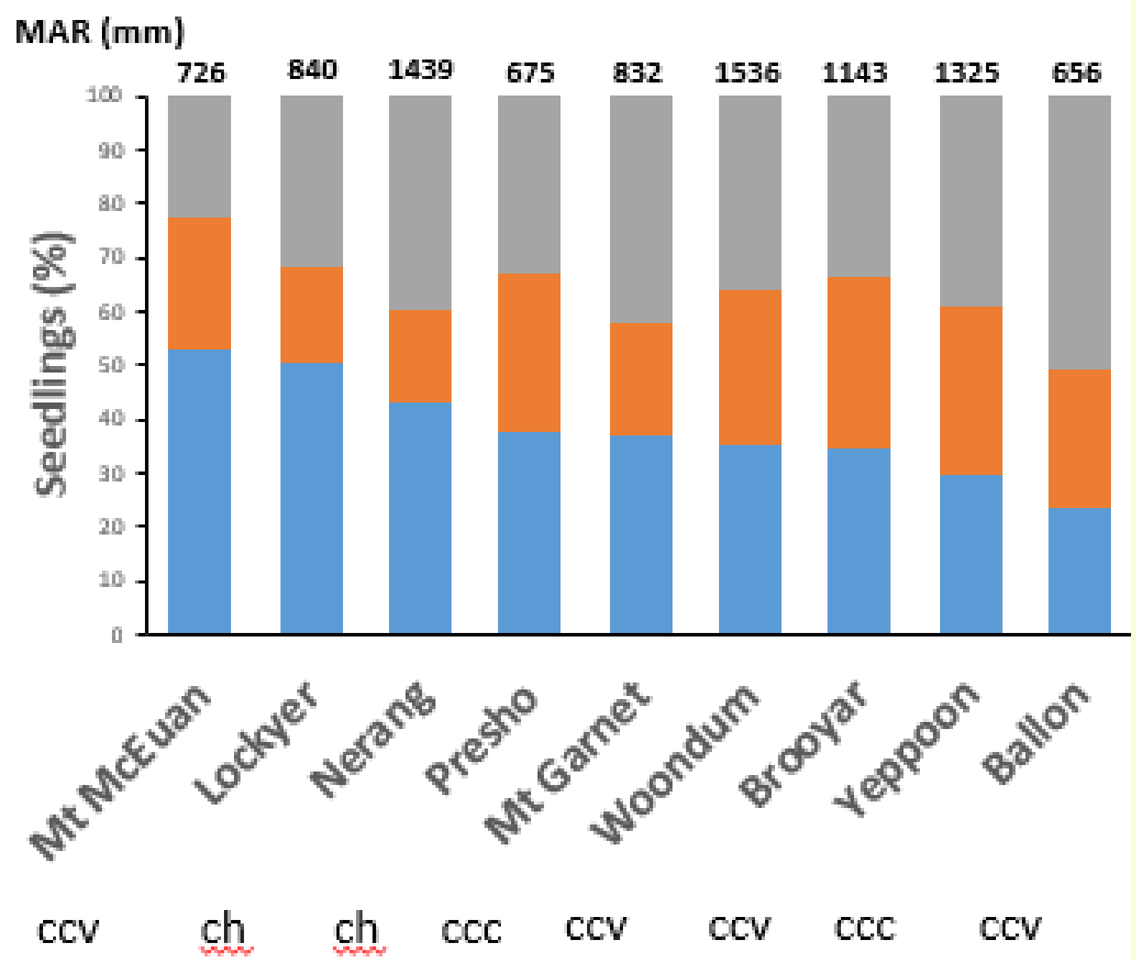
Spotted Gum species

- *C. citriodora* (ccc)
- *C. henryi* (ch)
- *C. variegata* (ccv)

Susceptible

Tolerant

Resistant



Resistance genotypes widespread.
Natural selection for resistance, and eventual recovery, is possible or likely in some/most populations, relative to decline rates.

Management options:

- **Germplasm capture (precautionary)**
- **Track resistance genetics**
- **Manage parentage ratios, or translocate (augment) with resistant natural genotypes in worse cases.**

Applied resistance genetics in eucalypts
-- South American commercial plantations

Two-year-old eurograndis clone.

Carnegie AJ (2012) The impact and management of Eucalyptus/Guava Rust in commercial forestry and native environments in Brazil and the USA: lessons for Australia. 2012 Gottstein Fellowship Report. Trustees of the J.W. Gottstein Memorial Trust Fund.

Resistance breeding for re-wilding faces extra challenges:

- **no commercial imperatives and investment**
- **Avoid genetic bottlenecking (infuse R-traits into wide range of wild genotypes) – massive seed or tissue capture**
- **Ecological, ethical, and cultural issues**
- **Few global models for plants**

The conservation response to Myrtle Rust will shape future capabilities for other pathogens …

… but will challenge our sector with difficult interventionist strategies.

- Resistance research and breeding (potentially cis- and transgenic, GE, other);
- Germplasm research and seed production areas on an unprecedented scale;
- Re-wilding strategies designed to avoid genetic bottle-necking;

– all of which pose technical, ecological, logistical and social challenges, with few Australian or international precedents, at least for plants.

The conservation sector needs to draw on the experience and technical knowledge of the biosecurity and plant health sector. Both sectors will need to help drive the cross-over.

A relevant model: American Chestnut (*Castanea dentata*)

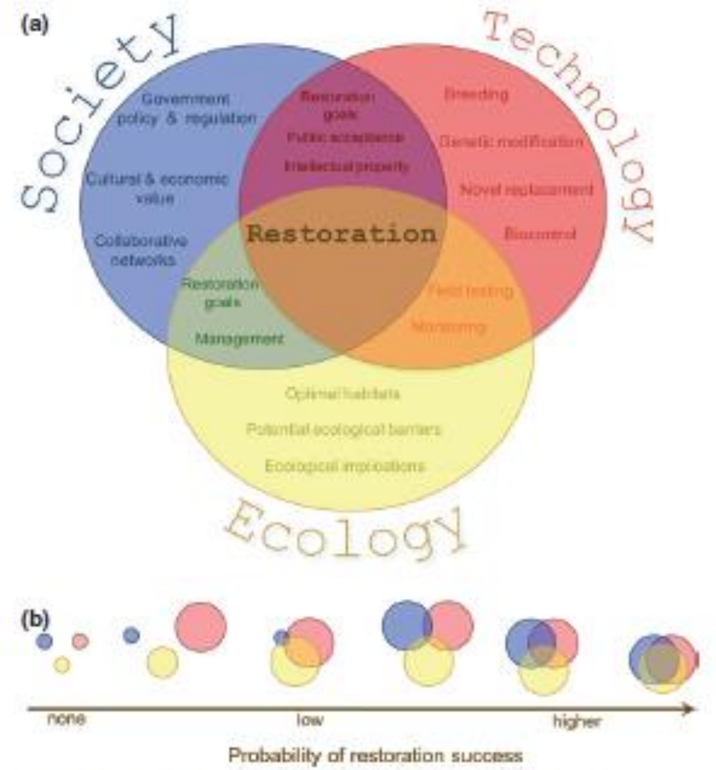


Fig. 2 Conceptual framework for restoration. (a) We identify three key spheres of expertise that underpin the process of using (re)introduction of a species as a tool in restoration: the society (blue), technology (red), and ecology (yellow) spheres. The area corresponds to the capacity of each sphere. Within each sphere and area of overlap (green, orange, and purple areas), we illustrate several key roles. The degree of overlap among all three spheres, illustrated in brown, represents the probability of achieving restoration success, which we define as meeting the restoration goals set through collaboration among members in all three spheres. (b) The framework predicts that restoration success increases as the capacity of the spheres and the degree of overlap (collaboration) among the spheres increase. If only one of the spheres has large capacity, for example, restoration success remains low because the degree of overlap is low. Similarly, restoration success will be low even when all spheres are large if the degree of overlap is low.

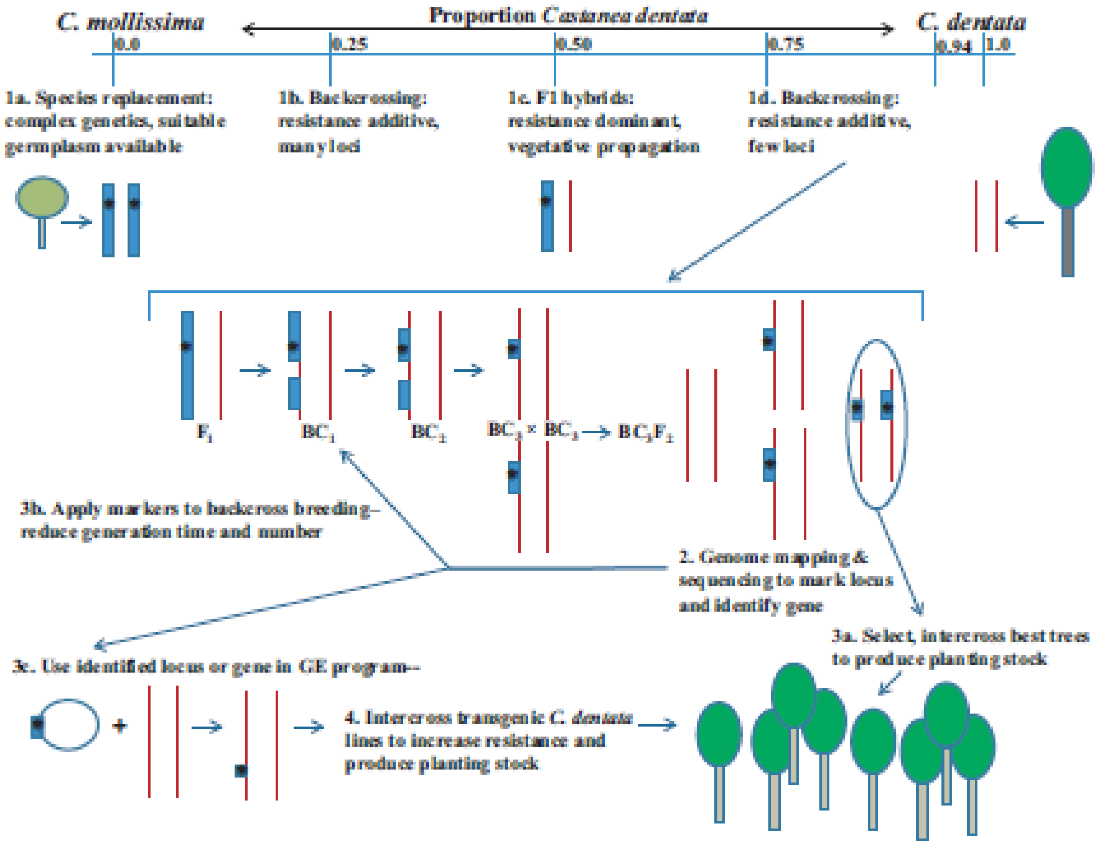


Fig. 6 Approaches for attaining resistance to chestnut blight, ranging from species replacement to various forms of hybridization and selection (1a to 1d). These methods represent a continuum in proportions of donor genome in new or recipient species, ranging from 100% under species replacement (1a) to c. 6% in backcross breeding to the BC_3F_2 generation (1d). The backcross breeding program provides optimal materials for genetically mapping blight resistance gene loci (2). Selected BC_3F_2 trees can be used in seed orchards as relatively true breeding parents to produce seeds for forest planting (3a). Once genetically mapped, markers can be used to facilitate backcross breeding in other crosses for increasing genetic diversity of the foundation species (3b). In addition, fine mapping and quantitative trait locus (QTL) sequencing can identify candidate genes for testing in genetic engineering (GE) lines of the foundation species (3c). Resistant GE lines can be further propagated and intercrossed to increase diversity and provide seeds for forest planting (4).

Jacobs DF, Dalgleish HJ, Nelson CD (2013) A conceptual framework for restoration of threatened plants: the effective model of American chestnut (*Castanea dentata*) reintroduction. (Tansley Review). *New Phytologist* 197(2): 378-393. http://www.jstor.org/stable/newphytologist.197.2.378