Summary of proceedings:

Australasian Myrtle Rust Conference

Sydney, 21–23 July 2023

and **Workshop on selection and breeding for Myrtle Rust-resistant plants**

26–27 June 2003

Australian Network for Plant Conservation Inc

Australasian Myrtle Rust Conference Sydney, 21–23 July 2023 and Workshop on selection and breeding for Myrtle Rust-resistant plants, 26–27 June. Summary of Proceedings.

Published on behalf of the Australasian Myrtle Rust Conference 2023 Organising Committee by the Australian Network for Plant Conservation Inc., Canberra, Australia. www.anpc.asn.au

ISBN 978-0-9752191-6-4

SUGGESTED CITATION: Makinson, R.O. (2023) Summary of Proceedings: Australasian Myrtle Rust Conference, Sydney, 21–23 July 2023, and workshop on selection and breeding for rust resistant plants, 26–27 June. Australian Network for Plant Conservation Inc., Canberra. https://www.anpc.asn.au/myrtle-rust/

Contact: Business Manager, Australian Network for Plant Conservation Inc., business@anpc.asn.au

Acknowledgement of First Nations

AMRC2023 was held on the unceded lands of the Gadigal people.

Participants came from many other lands of First Nations peoples across Australia and from Aotearoa New Zealand.

We acknowledge the Traditional Owners and custodians of the Lands on which we work and live. We recognise their continuing connection to land, water and community. We recognise their traditions of custodianship of the land and the things upon it.

We also pay our respects to Elders past, present and emerging.

Contents

Conference participants, Day 2. (Dan Turner, Head North Films)

Executive summary

Australia and Aotearoa New Zealand face a common threat to our natural heritage and natural resource base.

The exotic fungal disease Myrtle Rust, first detected in Australia in 2010 and in New Zealand in 2017, is attacking many species in the plant family Myrtaceae. This family is of fundamental ecological importance in both countries, is a rich repository of biological and genetic resources, and is an intrinsic element of our national and cultural identities.

In Australia, close to 50 native plant species are known or suspected to be declining towards extinction, some catastrophically, as a result of this disease. In New Zealand, all indigenous species of the family have been placed on the 'Threatened' list. An unknown number of associated species of flora, fauna, and fungi is affected in both countries.

Further strains of the same disease are known to exist overseas. These pose a further threat, and are recognised as a national biosecurity priority in both countries. As too, at the domestic level in Australia, is prevention of entry of Myrtle Rust to the mega-diverse south-west of Western Australia.

The biological threat process in both countries is broadly similar. AMRC2023 was intended to enhance trans-Tasman communication and knowledge transfer about this common threat, and met that aim. It also showed that institutional responses in the two countries have both similarities and differences. This report summarises the national update talks at the conference, and the presentation summaries show much of what is going on in some detail.

Considerable progress has been made globally in understanding fundamental features of the Myrtle Rust pathogen and its mode of action. Much of this work has been done in Australia and New Zealand, or has involved international collaborations with Australasian researchers. The summaries in this report convey much of the recent work in the fields of genomics, proteomics, rust strain diagnostics for biosecurity, and practical biosecurity techniques. Beginnings have been made in investigating host/pathogen interactions – the complex interplay of chemical attack and defence that determines whether the rust or the plant gains the upper hand – and towards identifying some of the particular genes in both organisms responsible for the process.

Effective fungicidal treatments for Myrtle Rust exist for use in cultivation, but have toxicity issues, and no chemical treatments yet exist suitable for use in the wild except at the very smallest of scales. However in recent months there has been exciting exploratory progress in the technique of ‘interference RNA’ as a non-toxic, non-GM short-term treatment, which if operationalised could be an important tool in the nursery and greenlife industries and for conservation management ex situ, and which would allow reduction in the use of toxic fungicides.

On the conservation side, there has been vital groundwork laid on both the research and the conservation action fronts. New Zealand researchers have begun to look at the unexpectedly rich micro-biota (fungi, lichens, and microflora) that occur on host species threatened by Myrtle Rust and are hence threatened with co-declines or co-extinctions, showing that these associated life forms number in the hundreds. Might some of them also have a role in helping their host plants against the rust? The cultural context in which conservation actions must be developed in New Zealand also has many lessons for Australia.

In Australia, emergency rescue actions in Queensland and New South Wales have saved representative living samples of four of the most threatened host species. A large ‘living library’ of plants in protected cultivation is the only option for future recovery actions, as these species are rapidly approaching extinction in the wild. We are in the very early stages of screening for rust-resistant genotypes in these species, as possible reinforcements for the dwindling wild populations. The challenge is to expand this to the many other species seriously affected.

Australia has not been used to responding to environmental disease threats of this scale and rapidity before, and after the initial and vigorous – but unsuccessful – eradication and containment attempts of 2010–12, there was no effective transition to any directed and funded ‘environmental’ response over the decadal time scales needed as the disease took hold. A small and largely science-based Myrtle Rust ‘Community of Concern’ has driven the development of a *National Action Plan for Myrtle Rust*, which has provided some guidance for investment and action by governments and others in the absence of a legislatively based response at national level, albeit without any surety of resources for implementation. State-level agencies in New South Wales and Queensland are now running complementary plans and projects for some species. However, resourcing overall still remains well below what is needed. A key element needing specific support is Indigenous engagement and co-design of conservation responses.

In New Zealand, a more integrated national response has been operative since 2018. This has focussed on science projects, with a national *Science Plan for Myrtle Rust*, a national stock-take of relevant published science, and a vigorous set of programs funded over half-decade time frames. Engagement with First Nations interests on the issue is far more advanced that in Australia, and engagement of other social stakeholder sectors has also been healthy. However, just as in Australia, there has, as yet, been relatively little funding for assessment of the effects of the disease in the wild, or for direct conservation actions.

Both countries urgently need renewed, focussed, and funded attention to this disease in the immediate future, to prevent species declines and extinctions, and to protect national assets.

AMRC2023 was the largest trans-Tasman Myrtle Rust knowledge-exchange event to date, with 103 in-person attendees across most fields of Myrtle Rust activity. It has equipped researchers and practitioners from both countries to cross-familiarise with progress, establish better collaboration, identify common and separate problems and potential solutions, and identify knowledge and resource gaps and needs – there are many.

This report presents a short precis of salient issues and major points to emerge from the conference, and then summaries of all conference presentations and workshop discussions.

Myrtle Rust damage on *Syzygium hodgkinsoniae*. Image: Geoff Pegg DAF QLD

Eleven reasons why we need strong national responses to the environmental threats posed by Myrtle Rust

The potential adverse effects of Myrtle Rust disease, in the absence of an effective remedial response, are multi-fold. Most of these received some level of attention in the conference:

- **Potential host-species extinctions and serious declines** are now being realised in Australia, with four host-plant species elevated to 'critically endangered' status, and about 45 more of identified immediate concern; all New Zealand Myrtaceae are now regarded as officially Threatened.
- **Declines or co-extinctions of associated flora, fauna and fungi** are likely, but there have been few investigations yet of these 'web of life' connections for Myrtle Rust host species.
- **Ecosystem-level changes** are already occurring; changes in the floristics and ecological function of one Australian forest ecosystem are reported at this conference.
- **Increase in short-term fire risk** is resulting from dead standing plant biomass; the long-term fire effects of changed floristics in different systems are unknown.
- **Potential increases in weed colonisation of priority natural ecosystems**; increased woody weed frequency has been noted in rust-affected forest.
- **Loss of fixed carbon due to plant death in forest ecosystems** is documented; the potential and rate for replacement carbon capture are unknown.
- **Loss of social and cultural heritage, and aspects of national and local identity**: these effects cut across all social groups, but are especially acute for First Nations peoples.
- **Loss of identified values for World Heritage Areas**: at least four WHAs in Australia are already affected.
- **Potential loss of ecological function**: for example, erosion prevention (*Tristaniopsis exiliflora* in Australia's Great Barrier Reef catchment; kānuka in degraded landscapes in New Zealand; *Melaleuca* species in Australia floodplains and freshwater wetlands); and maintenance of water quality and freshwater aquatic habitat (*Melaleuca* species).
- **Loss of known and unknown (yet to be evaluated) biological, economic, and cultural assets**: the Myrtaceae is a family rich in biochemical and genetic resources, providing many 'ecological services' and having a vast range of medicinal and culinary uses, resources for climate change adaptation, wild-stock for ornamental and production horticulture, food and wood products, and many other attributes.
- **Potential loss of public confidence in biosecurity processes and response capabilities**: a robust and coordinated national response, directed at remediation of impacts, would play a major role in building confidence and capacity for future environmental biosecurity threats.

Dead Native Guava trees at Bongil Bongil National Park, NSW, 2013, only two years after the arrival of Myrtle Rust. In recent surveys in NSW and QLD, no adult trees remain of this once common rainforest plant. Photo: Peter Entwistle

Key messages from the conference discussions

Facing future threats

Myrtle Rust will not be the last aggressive environmental pathogen to enter the Australasian region. Biosecurity agencies recognise others 'waiting in the wings'. Global movement of such threats is increasing. Neither country was prepared for such a broad-spectrum, fast-moving disease in the natural environment. If we do not learn the lessons of Myrtle Rust, and move to a more active response, we will not improve our readiness for the next such pathogen.

Time is not on our side

In Australia, several species have crashed towards extinction since 2010. The lack of a conservation response prior to 2019 led to a very narrow window of time to 'rescue' living samples of some of these species as they dwindle towards extinction. This is the raw material with which it may be possible to breed stronger, rust-resistant stock to reinforce the survivors. The technique is feasible, is in use overseas, and is similar in principle to the selection and rewilding programs for warming-tolerant Great Barrier Reef coral species currently underway. Other species in steep decline from Myrtle Rust have yet to be sampled in the same way. The longer we take, the more of their natural genetic diversity will be lost.

Many knowledge gaps need to be filled

As papers at this conference show, progress has been made to fill some of the basic knowledge gaps about the pathogen, as a prelude to investigating its mode of action in detail. Less progress has been made in understanding the at-risk plant species themselves – their original and remaining extent and abundance, and the features that make them susceptible or resistant to the disease. We know next to nothing about which of their many associated species of flora, fauna and fungi, may be at risk of co-declines and co-extinctions.

Coordination is needed at national levels, and sustained directed funding

A piecemeal approach based only on competitive short term funding will not allow us to meet the challenge. Just as with serious agricultural pathogen threats, sustained and planned investment is needed over decadal time frames. This needs to encompass basic and applied research, conservation action, and cultural co-design of the response. All are urgent.

Some areas of action and research that should be included in renewed planning and investment in both countries can be easily nominated – these are however not an exhaustive list. Bodies with funding or oversight responsibilities for the environmental effects of this disease should engage closely with the Myrtle Rust community of concern, including First Nations stakeholders, to generate a planned approach for all potentially fruitful areas of action and research.

Specific areas of research needing investment

- Ecology of the host species, including their associated biota.
- 'Omics' investigations (transcriptomics, proteomics, metabolomics) to clarify the mode of interaction between plant and pathogen.
- Investigation of what makes a plant, and its various tissues, susceptible or resistant.
- Incorporation of First Nations perspectives in setting and executing goals and processes.
- Potential novel treatments for Myrtle Rust control, particularly interference RNA (RNAi).
- Germplasm conservation, including seed storage, tissue culture, and cryopreservation.
- Ecosystem-level impacts of Myrtle Rust, and remedial options.

Specific areas of conservation action needing investment

- Expedited development of conservation planning for Myrtle Rust-affected species and ecosystems, dovetailed across jurisdictional boundaries.
- Expansion and support of collaborations across jurisdictional and agency boundaries, recognising the national and supranational nature of the threat.
- Capture and maintenance of highly representative germplasm from priority species, as a basis for downstream conservation actions.
- Gathering of baseline data on the affected species and ecosystems.
- Establishment and expansion of First Nations input to conservation planning; co-design as a principle wherever capabilities allow.
- Establishment, with a decadal-scale perspective, of a supported network of screening and breeding programs and sites, and associated capabilities.
- Expanded genomic investigations of at-risk species to optimise conservation strategies.
- Regional investment in capabilities and action in north-east Queensland.
- Field assessment of Myrtle Rust impacts, and establishment of long-term monitoring sites.

Specific areas of biosecurity action needing investment

- Continued improvement in diagnostics for new strains or novel emergent genotypes.
- Public awareness, including a sustained and a resourced ‘citizen science’ component.
- Development of the First Nations role in on-country surveillance and assessment.
- Continued improvement in surveillance and detection networks and readiness plans, especially for priority regions such as Western Australia.
- Continued development of detection technologies.
- Expansion of knowledge of the interplay between climate, weather, spore-load, and host species, to better understand the dynamics of the disease in the wild and in cultivation.

National capabilities

- Embedded planning and resourcing for medium term (at least decadal-scale) research and action, with adequate review and renewal options to avoid funding ‘cliffs’ and associated loss of momentum and expertise.
- Supported and stable national information hubs and data directories and/or repositories.
- The attention of authorities is drawn to the progressive decline in recent decades of the scientific and technical labour force and skills formation needed to assure adequate response to environmental biosecurity threats.
- Streamlining and appropriate updating of permit arrangements for control chemicals.

About AMRC2023

The Australasian Myrtle Rust Conference 2023 (AMRC2023) was the latest in a series of national and trans-Tasman events to bring together those involved in responding to the threat of Myrtle Rust plant disease in the region. Most previous events, and this one, have been primarily organised and driven by the Myrtle Rust 'community of concern', comprising plant health and plant pathology researchers, biodiversity conservation researchers and practitioners, and (particularly in Aotearoa New Zealand) First Nations stakeholders.

Previous Myrtle Rust conferences and workshops in the Australasian Region

Many smaller meetings and specific program gatherings are omitted.

Australia

- Myrtle Rust Research & Development Planning Workshop, Brisbane Qld, 28–29 Sept. 2011
- Myrtle Rust Research & Development Planning Workshop, Brisbane Qld, 19–20 June 2012
- Myrtle Rust in natural ecosystems – National Workshop, Canberra ACT, 12 Dec. 2012
- Myrtle Rust [National] Workshop, Brisbane Qld, 19–20 April 2016
- Myrtle Rust Symposium, Ballina NSW, 23–25 March 2021

Aotearoa New Zealand

- Workshop – The threats posed to New Zealand from myrtle rust – international perspectives, potential impacts and actions required, Wellington, 6–7 Dec. 2016
- Myrtle Rust Symposium, Auckland, 28 Aug. 2017
- Myrtle Rust Science Symposium, Wellington, Dec. 2018
- Myrtle Rust Science Symposium, Auckland, 9–10 Sept. 2019

The genesis of AMRC2023, and its eventual theme 'Where to from here?', reflected a substantial increase in knowledge of the pathogen and its impacts in recent years, even since the Ballina Symposium of 2021 (videos of which are at https://www.apbsf.org.au/myrtle-rust/), and some parallel progress made in applied conservation actions for species affected by the disease in the wild. In the same period there has been progress in knowledge and practice relevant to management of the disease in crop and amenity plantings.

The conference originated in trans-Tasman discussions between a small number of researchers in late 2022, and took concrete form with the initiative of Dr Peri Tobias to host an event at the University of Sydney. Originally envisaged as a relatively small research-oriented gathering, the scope rapidly broadened to meet a felt need for direct discussions and information exchange right across the Myrtle Rust community of concern and practice.

AMRC2023 Conference underway. Photo: Dan Turner

The core Organising Committee for AMRC2023 comprised:

- **Peri Tobias**, University of Sydney, Australia
- **Stuart Fraser**, Scion Research, NZ
- **Mahajabeen Padamsee**, Manaaki Whenua Landcare Research, New Zealand
- **Alyssa Martino**, University of Sydney, Australia
- **Beccy Ganley**, Plant & Food Research, New Zealand
- **Renee Johansen**, then of Manaaki Whenua-Landcare Research and the Beyond Myrtle Rust programme, New Zealand
- **Craig Stehn**, NSW Department of Environments and Planning, Saving Our Species Program, Australia
- **Grant Smith**, Plant & Food Research, New Zealand
- **Angus Carnegie**, NSW Department of Primary Industries, Australia
- **Geoff Pegg**, Queensland Department of Agriculture and Fisheries
- **Bob Makinson**, Australian Network for Plant Conservation Inc.

Administrative and financial management support was provided by Jo Lynch (Australian Network for Plant Conservation Inc., www.anpc.asn.au).

Conference organisation and logistics were by Cameron Armstrong and Karen Armstrong (Essential Experiences Event Management, www.essentialexperiences.com.au).

AMRC would not have been possible without the generous financial and in-kind backing of the following sponsors and supporting organisations:

With thanks to our sponsors

scion™ FORESTS ▪ PRODUCTS ▪ INNOVATION

Australian Government Department of Climate Change, Energy, the Environment and Water

Plant Health AUSTRALIA

Biosecurity New Zealand Ministry for Primary Industries Manatū Ahu Matua

Australasian Plant Pathology Society (APPS)

THE UNIVERSITY OF SYDNEY Institute of Agriculture

With thanks to our supporters

Queensland Government Department of Environment & Science

Australian Network for Plant Conservation Inc

AUSTRALASIAN MYRTLE RUST CONFERENCE

In particular we thank the Australian Government for crucial funding assistance, and – for venues and related assistance – the University of Sydney (conference) and Botanic Gardens of Sydney (workshop). Readers should note that this document is a conference record and is not a product of, and does not necessarily reflect the views of, any of these organisations.

Conference thematics and demographics

OVERALL CONFERENCE THEME: "Where to from here?"

THEMATIC SECTIONS: 40 presentations overall, ten posters.

- Opening updates on the status of Myrtle Rust and response to it in the Australasian region (2 presentations)
- Fundamental science of the pathogen and host (12 presentations, 4 posters)
- Indigenous perspectives (3 presentations, 1 poster)
- Biosecurity (5 presentations, 3 posters)
- Environment and Ecology (6 presentations, 2 posters)
- Conservation and Applied Science (14 presentations, two workshops)
- Workshop: Conservation and Research gaps and the way forward

CONFERENCE OPENING ADDRESS: **Dr Bertie Hennecke**, Australian Chief Environmental Biosecurity Officer, on 'Australia's Biosecurity Outlook: An environmental biosecurity perspective'.

KEYNOTE PRESENTATIONS:

- **Dr Richard Sniezko**, US Department of Agriculture Forest Service, Dorena Genetic Resource Center, Oregon: 'Developing disease resistance tree populations for restoration: lessons from successful US resistance programs to apply to Myrtle Rust'.
- **Roanne Sutherland**, New Zealand Department of Conservation: 'A conservation perspective of managing myrtle rust in Aotearoa New Zealand'.

The Conference program is appended to this report.

International guest speaker Dr Richard Sniezko from the US Department of Agriculture Forest Service, presenting on developing disease resistant tree populations for restoration. Photo: Dan Turner

REGISTRATIONS RECEIVED: 103 (29 New Zealand, 1 USA, 73 Australian or Australia-based).

GENDER RATIO (F:M, apparent binary only – identifications were not solicited): 51:52

VENUE: University of Sydney, Holme Building.

ACCESS AND RECORDINGS: Conference attendance was by in-person attendance only (not live on-line). Video recordings of all presentations are on the Australian Network for Plant Conservation YouTube channel at https://www.youtube.com/playlist?list=PLuPMH5OJZz0ECW5mA5wyx2v8C4SZjTsco

Post-conference workshop, 26th and 27th June 2023

AMRC2023 was followed, with an overlapping attendance, by a two-day 'hybrid' workshop (in-person and live on-line). This workshop took a deeper dive into the options and issues around **selecting and breeding from wild genotypes for myrtle rust resistance as part of a conservation strategy**, a theme that was the also the subject of some conference presentations. Like the conference, the workshop was able to take advantage of the presence of Dr Richard Sniezko, a world expert in this area of work.

All AMRC registrants were invited, and an additional invitation list circulated to others thought likely to have an interest or expertise that would be needed as activity grows in this area of conservation action. There was no registration fee for this extra workshop. Discussion was recorded, but main points, presented later in this report, were also scribed.

The workshop was held at The Royal Botanic Gardens, part of Botanic Gardens of Sydney, and we are grateful for that organisation's support in provision of the venue and recording and communications facilities, catering, and for the presence of a number of their staff.

The goals of the workshop (here slightly edited), were:

- To develop a common level of understanding among a core body of Myrtle Rust practitioners of the global (and particularly the North American) experience in successful and unsuccessful disease resistance breeding programs (RBPs) in woody plants, especially for rusts, and the features that promote success.
- To develop a common understanding on the ways in which RBPs directed at biodiversity conservation goals differ from those for commercial crop and timber species, e.g. in width of genetic base, maintenance of ecological fidelity and variation, and other aspects.
- To generate an overview of the human and institutional landscape within which an RBP model must develop.

- To generate an overview of the existing expertise and facilities, government and non-government, that should be investigated in more detail for RBP involvement.
- To develop an agreed flexible and adaptive conceptual architecture for an RBP meta-program in the A/NZ context, noting that in Australia's case up to 50 or so species may be eventual candidates for inclusion, such is the scale of the Myrtle Rust problem.
- To develop priority directions for scoping studies, information assembly, communications, and concept promotion in pursuit of integrated RBP in the two countries.

The workshop was not aimed at development of any specific funding proposal.

A set of discussion starter topics were prepared for each of the following areas:

- practical workflow of resistance selection and breeding
- case study (already in early stages of implementation): Scrub Turpentine *Rhodamnia rubescens*
- expertise needed
- facilities needed
- candidate species.

As a resource for the discussions, a selection of papers and other material on international cases of disease resistance breeding for conservation in woody plants, including several papers and a webinar by Dr Sniezko, were made available in weeks prior to the event on a password-accessible web-page: https://www.anpc.asn.au/myrtle-rust/amrc2023-sniezko-workshops/, password *AMRC2023*.

WORKSHOP REGISTRATIONS: 40 people (probably more in attendance at some points via some Zoom nodes). 28 registrants were Australian-based, and 12 from New Zealand.

About the conference and workshop summaries in this report

All conference presentations have been summarised below from notes taken in the course of conference, and from a full review of video/audio recordings. For presented papers, drafts of each summary were emailed to the presenter for a check and any necessary corrections. Close to forty presenters responded; all corrections or preferred forms of words received have been incorporated here. Workshop summaries are edited down from notes on the days, recordings, and from session scribe notes. Responsibility for any residual errors is mine – ROM.

About Myrtle Rust

Myrtle Rust disease is caused by the pathogenic rust-fungus *Austropuccinia psidii*, of South American origin. Myrtle Rust affects only species in the plant family Myrtaceae. It attacks new plant growth (seedlings, seasonal flush, and resprouts). Progressive cycles of infection may retard plant growth and flowering, and in severely affected plants eventually starves them to death through progressive defoliation.

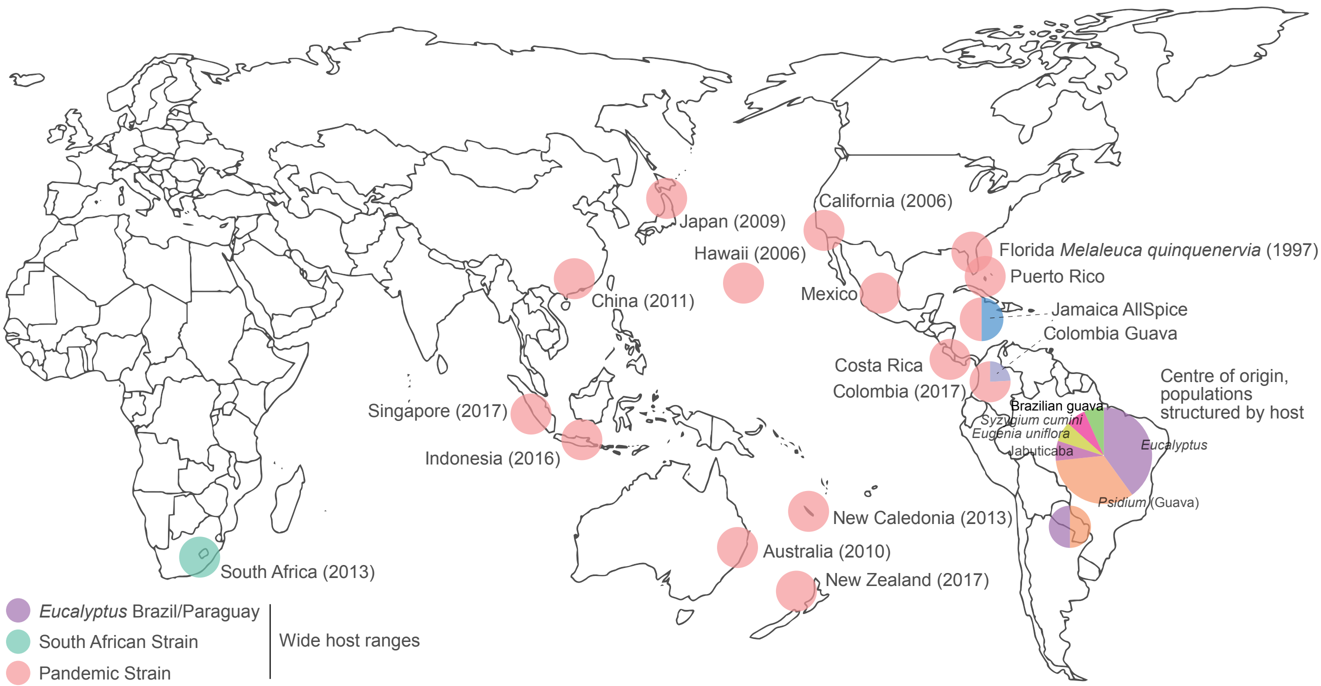
Myrtle Rust affects only species in the plant family Myrtaceae. It has an exceptionally wide host range. World-wide, over 500 plant species and sub-species are known to be susceptible to infection at some level, including more than 350 native Australian species, and most or all of the indigenous species in New Zealand. Not all such host species are equally susceptible; some consistently have minor levels of infection, others may 'outgrow' the disease, but many are highly susceptible and are soon overwhelmed by it.

The plant family Myrtaceae is of fundamental ecological and cultural importance in Australia and Aotearoa New Zealand, and in neighbouring parts of the south-western Pacific. In Australia it includes paperbarks, bottlebrushes, tea-trees, eucalypts, and lillipillies, and many more (c. 2735 species and subspecies). In Aotearoa New Zealand, it includes pōhutakawa, mānuka and kānuka, and several rātā species, among others (38 native Myrtaceae taxa across 6 genera in most sources, although recent taxonomic work may see the number of taxa recognised at species rank drop to 19).

Myrtle Rust is a broad-spectrum plant disease that poses a serious and urgent threat to many species in this plant family. It is recognised as a serious international biosecurity threat economically and environmentally (references 1, 2, 3).

Austropuccinia psidii is not a direct threat to human or animal health, although loss of Myrtaceae species habitat may affect some animal species, human commercial enterprises, Indigenous and non-Indigenous social and cultural values and amenity, and ecosystem integrity. In Australia, at least five World Heritage Areas are affected so far.

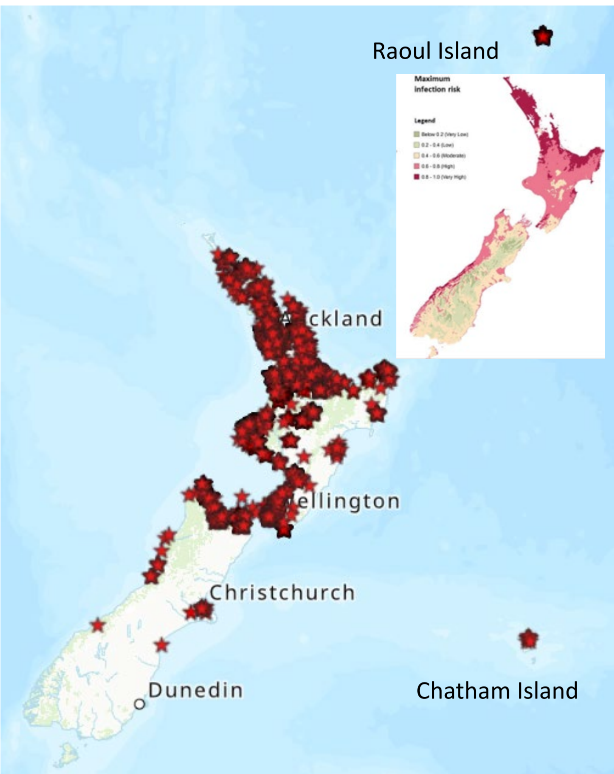
Myrtle Rust's arrival in the south-western Pacific region is recent: Australia in 2010, New Caledonia in 2013, New Zealand in 2017.



Global spread of *Austropuccinia psidii*, the Myrtle Rust pathogen. Image courtesy of Alistair McTaggart.

Myrtle Rust is a disease of moister areas, currently including much of the North Island of New Zealand, parts of the South Island, and almost the entire east coast of Australia. It is also established in cultivation in the Australian States of Victoria and Tasmania, but is not yet known in wild vegetation in those States. It is established in the wild in the far north of Australia's Northern Territory, and very marginally (at June 2023) in the far north east of Western Australia. Myrtle Rust is expected to be capable of establishment in the far south-west of Western Australia, a biodiversity hotspot with a very rich Myrtaceae flora, most of which is expected to be susceptible – prevention of the pathogen's arrival in this region is a domestic biosecurity priority. Myrtle Rust is not a threat in Australia's drier ecosystems.

Myrtle Rust distribution in Australia, 2010–2023. Image courtesy of Geoff Pegg, DAF Queensland.



Myrtle Rust in Aotearoa New Zealand.

MAIN MAP: Distribution at mid-2023.
INSET: Climatic risk profile map from www.myrtlerust.com, from the Myrtle Rust model developed by Dr Robert Beresford (Plant & Food Research). Graphic compiled by Roanne Sutherland (DoC), and Beccy Ganley (P&FR).

Many cultivated species of Myrtaceae in both countries, both native and introduced, are susceptible to Myrtle Rust. In many commercial situations the disease can be controlled by more or less frequent application of fungicides, with adverse associated costs, human and environmental safety issues, and potential loss of organic certification. In the absence of better control treatments, there is a disincentive for further horticultural development of the rich genetic resources of the family in both countries. At a wider level, the family represents an enormous trove of genetic, phytochemical, and ecological resources, many of which are not yet evaluated.

This 2023 conference and workshop had as its primary areas of focus the basic science of the disease, and its impacts on wild biodiversity and cultural values. Nevertheless, the outcomes of AMRC2023, like its precursors, have relevance to the need to keep both cultivated and wild plants healthy, although by different means. The effort to combat Myrtle Rust has benefitted from strong collaboration and expertise exchange between practitioners whose main focus is on agricultural situations, those who are primarily concerned with wild plant conservation, and those whose concern is for the cultural values regardless of the 'wild/non-wild' dichotomy.

The impacts of Myrtle Rust on Indigenous communities are broader than ecological and industry values. Country, Culture and Community are all connected, they are not separate. Myrtle Rust impacts the health of country and the ability to maintain cultural practices and values, and therefore impedes the health of Indigenous communities. Many Myrtaceae are edible and/or have medicinal properties, and many are culturally significant to First Nations – and to others – in various ways.

Biodiversity impacts

Numerous native species in both countries, some of them previously common, face rapid decline and/or extinction in the wild due to Myrtle Rust. Some of these species were already threatened by other processes prior to the pathogen's arrival, but many were not, including some that were widespread and of no previous conservation concern.

In Australia, several Myrtle Rust-affected species are legislatively listed in various subcategories under the 'Threatened' umbrella term in Queensland, New South Wales, and nationally. Four species are currently listed in all three jurisdictions as Critically Endangered. However, the assessment process for further listings lags well behind the reality of declines in the wild for many species, and this inhibits the availability of funding and possibilities for action. A *National Action Plan for Myrtle Rust in Australia* (4) nominates 49 species of concern for investigation and/or definite action, in categories from 'emergency' to 'medium' priority. A recent survey in Queensland rainforests (ref. 5) generated an overlapping list of 16 species on a trajectory of imminent extinction within one plant generation as a result of Myrtle Rust, and a further 20 species of serious concern but requiring further evaluation. To date, funding for assessment and conservation actions has been available for only a handful of these species.

In Aotearoa New Zealand, all indigenous species of Myrtaceae were placed in the umbrella category of 'Threatened' in 2017, because of Myrtle Rust; within this, they are assigned to various sub-categories of endangerment according to other criteria. As in Australia, funding for field surveys has been inadequate to critically assess most species.

The assessment of impacts of Myrtle Rust on species and ecosystems in both Australia and Aotearoa New Zealand lags well behind the reality – neither country yet has adequate monitoring of the impacts 'in the wild' or the damage being done to cultural values.

The potential for ecological cascade effects deriving from the decline of Myrtle Rust host plants is uncertain, but secondary declines, extinctions, or other adverse ecological effects are likely. One highly susceptible Australian species, Broad-leaved Paperbark (*Melaleuca quinquenervia*), is a keystone species for very large areas of riparian margins and freshwater wetlands in eastern Australia – there will be major issues for water quality, aquatic biota, and erosion in the event of its serious decline. In New Zealand, two Myrtle Rust host species alone (*Lophomyrtus* species) have been found to sustain associated communities of over 200 micro-flora and micro-fungi species.

Myrtle Rust has a combination of features that both accentuate its threat status and make management and recovery of affected species in the wild particularly difficult:

- Airborne spores, extremely mobile by wind, as well as by human and some animal vectors.
- Rapid multiplication: a life cycle 8-12 days in optimal conditions.
- An enormous host range that helps to perpetuate local outbreaks and overall spore-load.
- No practicable means at present of short-term management safely deployable in the wild.

A continuing biosecurity priority

The western Pacific region currently has only one strain (or biotype) of *Austropuccinia psidii*. Further strains of the pathogen, known to exist in South and Central America and South Africa could, if introduced to the south-west Pacific region, escalate the threat, and prevention of their arrival is regarded as a national biosecurity priority for Australia (4, 6, 7). One of these further strains is particularly aggressive on eucalypts in South America. A vigorous and sustained national response to the one strain already present in the region will greatly advance regional preparedness for further strains, and for environmental biosecurity in general.

Key websites, Aotearoa New Zealand

New Zealand Myrtle Rust website: https://www.myrtlerust.org.nz/

New Zealand Myrtle Rust outputs to date:
https://data.bioheritage.nz/dataset/myrtle-rust-science-stocktake

Beyond Myrtle Rust program: https://www.landcareresearch.co.nz/discover-our-research/biodiversity-biosecurity/ecosystem-resilience/beyond-myrtle-rust/

Beyond Myrtle Rust webinar series: https://www.landcareresearch.co.nz/discover-our-research/biodiversity-biosecurity/ecosystem-resilience/beyond-myrtle-rust/webinar-series/

Ngā Rākau Taketake: https://bioheritage.nz/research/saving-our-iconic-trees/

New Zealand *Myrtle Rust Science Plan* (2019):
https://www.myrtlerust.org.nz/assets/Uploads/Myrtle-Rust-Science-Plan.pdf

New Zealand *Myrtle Rust Strategy*:
https://www.myrtlerust.org.nz/how-you-can-help/myrtle-rust-strategy/

Key websites, Australia

Australian Network for Plant Conservation *Myrtle Rust information hub*:
https://www.anpc.asn.au/myrtle-rust/

Myrtle Rust in Australia – A National Action Plan. (2020).
https://www.anpc.asn.au/wp-content/uploads/2020/11/Myrtle-Rust-National-Action-Plan-2020.pdf

Myrtle rust: Biosecurity alert (Western Australia):
https://www.agric.wa.gov.au/plant-biosecurity/myrtle-rust-threat-western-australia

Global information

Global Host List: Soewarto *et al*. (2019) *Austropuccinia psidii* (Myrtle Rust) Global Host List. Version 4.
https://www.anpc.asn.au/myrtle-rust/

Austropuccinia psidii (myrtle rust) – CABI Factsheet (Carnegie & Giblin 2014).
https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.45846

References

1. Coutinho *et al*. (1998) Eucalyptus rust: A disease with the potential for serious international implications. *Plant Disease* 82: 819-825.

2. Glen, M., *et al*. (2007) *Puccinia psidii*: a threat to the Australian environment and economy – a review. *Australasian Plant Pathology*, 36, 1-16.

3. Biosecurity New Zealand (2019) New Zealand Myrtle Rust Strategy 2019–2023. https://www.myrtlerust.org.nz/assets/Uploads/Myrtle-Rust-Strategy-web3.pdf

4. Makinson, Pegg, & Carnegie (2020) Myrtle Rust in Australia – a National Action Plan, Australian Plant Biosecurity Science Foundation, Canberra. https://www.anpc.asn.au/wp-content/uploads/2020/11/Myrtle-Rust-National-Action-Plan-2020.pdf

5. Fensham *et al*. (2021) Unprecedented extinction of tree species by fungal disease. *Biological Conservation* 261: 109276. https://doi.org/10.1016/j.biocon.2021.1092763.

6. The [Australian] *National Priority List of Exotic Environmental Pests, Weeds and Diseases* (2020). https://www.agriculture.gov.au/biosecurity-trade/policy/environmental/priority-list

7. National Priority Plant Pests (2019). https://www.agriculture.gov.au/biosecurity-trade/pests-diseases-weeds/plant/national-priority-plant-pests-2019

Conference summary of proceedings

21–23 June 2023

DAY 1

Welcome to country, and Māori acknowledgement

A Welcome to Country, and Acknowledgement of the Gadigal people on whose country the conference was held, was given by Auntie Joan Bell, a Board Member of the Sydney Metropolitan Local Aboriginal Land Council.

A response to the Welcome to Country, on behalf of Aotearoa New Zealand attendees, was led by Mr Alby Marsh (B3 - Better Border Biosecurity, NZ), acknowledging the Gadigal people and acknowledging the guidance of Atua and ancestors.

Opening Address – Dr Bertie Hennecke, Australian Chief Environmental Biosecurity Officer (ACEBO)

Dr Hennecke noted the relatively recent creation (Oct. 2018) of the ACEBO position, arising from recommendations of a Senate Inquiry and an external review in 2017 of Australia's Intergovernmental Agreement on Biosecurity (IGAB) arrangements. The ACEBO is one of the 'Three Chiefs' in the biosecurity space, alongside the Chief Veterinary Officer (CVO – Dr Mark Schipp) and the Australian Chief Plant Protection Officer (ACPPO – Dr Gabrielle Vivian-Smith); all three are based in the Commonwealth Department of Agriculture Fisheries and Forestry. The ACEBO works closely with the Commonwealth's Threatened Species Commissioner (Dr Fiona Fraser) in the Department currently known as DCCEEW. The ACEBO is the national point of notification for environmental pest and disease detections and responses (acebo@aff.gov.au).

Dr Hennecke stressed the importance of broadening knowledge and active use of the 2020 *National Priority List of Exotic Environmental Pests, Weeds and Diseases* (abbreviated to the *Exotic Environmental Pest List* (EEPL - https://www.agriculture.gov.au/biosecurity-trade/policy/environmental/priority-list), which is specific to environmental pest and pathogen threats yet to arrive in Australia, and the somewhat broader 2019 *National Priority Plant Pest List* (NPPP - https://www.agriculture.gov.au/sites/default/files/documents/australias-national-priority-plant-pests.pdf) which includes both environmental and agricultural threats. Both these lists include 'Exotic strains' of the Myrtle Rust pathogen *Austropuccins psidii*, meaning strains or biotypes not yet present in Australia (we have only the 'pandemic strain' so far). The ACEBO referred to possible pathways for the arrival of such strains, and the general procedures in place to impede, detect, or interrupt entry.

Updates on the status of myrtle rust and response in the Australasian region

- **Australian perspectives: Bob Makinson** and **Geoff Pegg**
- **New Zealand perspectives: Beccy Ganley** and **Roanne Sutherland**

AUSTRALIA

[See the 'About Myrtle Rust' section of this report for key Australian and global web resources.]

Geoff Pegg briefly reviewed the global distribution of the variant strains of Myrtle Rust, and posed the question of whether, if a new strain arrived in eastern Australia, where one strain is already present, would we be likely or not to detect it and respond in a timely way – it may well be difficult to convince anyone to invoke a biosecurity response for that contingency. So maybe we need to look proactively at what these different strains might mean in terms of different host ranges and their potential ability to evade any resistance traits for the pandemic strain. (An outbreak of any strain in the south-west of Western Australia would be a different matter, and after the eastern Australian experience a strong institutional incursion response could be expected).

Geoff then reviewed the current within-Australia distribution, noting that in Victoria and Tasmania the pathogen is still not known from the natural ecosystem, only from cultivation. In Victoria there is evidence that it is moving around in park and garden situations, and is gradually drifting east towards East Gippsland. In the Northern Territory the rust mainly hugs the coastline, but active surveillance is lacking.

In eastern Australia, impacts on the severely affected species tend to be on new growth at all life stages, from seedlings to adult trees. In less susceptible species, such as the eucalypts, there is more of a differential age-effect.

The current host range in Australia is more than 380 species. Not all are seriously affected. Some species are slower starters than others in the decline process, and impacts on some species vary from place to place. We still have only a single long-term monitoring site for Myrtle Rust, in the Tallebudgera Valley in south-east Queensland. At that site, three formerly abundant species have effectively disappeared from study plots, and floristically the Myrtaceae-dominated mid-storey is being replaced by non-Myrtaceae species. Outside the plots, in 2021, mortality rates were estimated as 3,400 dead/dying trees per hectare, with 91% of under- and mid-storey Myrtaceae dead or dying.

The 2019-20 megafires were followed by massive regrowth of many species, including resprouting of many standing Myrtaceae – the regenerant trees are of course dependent on this resprout growth for survival. But this new growth can be very prone to Myrtle Rust infection. For two *Melaleuca* species, over 18 months post-fire, death rates of adult trees attempting to resprout ranged 50–65%, and flowering was greatly reduced. We have no idea as yet whether natural selection for rust tolerance will be able to sustain these species or not. Seedling recruitment, from a limited set of single-visit assessments, suggests significant levels of infection in seedlings.

As yet we have only scratched the surface with respect to the cultural significance of Myrtaceae, and of Indigenous knowledge that might contribute to management. Efforts to build a network of collaboration in this area are underway [see talks by Tilly Davis and Aj Perkins].

Screening for resistance has until very recently been largely focussed on commercial species (in *Eucalyptus* and *Corymbia*, plus Lemon Myrtle *Backhousia citriodora*, and Tea Tree *Melaleuca alternifolia*), simply because broad ex situ collections existed for these. Peri Tobias has done screening work for resistance in the horticulturally important WA species Waxflower *Chamelaucium uncinatum* (no resistance detected), and there has been limited work in *Melaleuca*.

What lessons have been learnt?

- Are we better placed in the environmental biosecurity space? Probably yes, but still nowhere near comparable to the response capability that applies to agricultural species.
- Is there an appropriate Indigenous voice when it comes to environmental biosecurity? Not yet, and we have no easy path to achieving this; consistent engagement is key.
- Is ‘the message’ about biosecurity getting out there? Not effectively enough – there are still large uncontrolled human pathways for illegal imports. Do we just educate? Do we focus on the next generation? Our video ‘Myrtle Rust – the Silent Killer’ got a lot of hits, but how do we estimate its effect? More discussion of the messaging strategy is needed.

Bob Makinson reiterated the call to promote awareness of the EEPL list [see Hennecke address above] and the yet-to-arrive pathogens on it, as a first step towards preparedness for them – there has been little or no awareness raising about EEPL in the environment sector to date.

He then outlined the development of the Australian *National Action Plan for Myrtle Rust* (MRNAP) since 2016 by the community of practice concerned with the environmental impacts of the disease, and the influence the Plan is gradually having on research, conservation action, and government recognition of the threat. He stressed the need for government agencies to re-orient away from dealing with Myrtle Rust only in the context of legislatively listed threatened species, as these lists lag years behind actual impacts for this fast-acting disease; rather we need to address it for affected species and ecosystems regardless of formal status, and as an overall threatening process. The current (2020) iteration of the MRNAP flags 49 species as needing immediate action.

Makinson stressed key messages as:

- the need to communicate across jurisdictional, departmental and disciplinary boundaries
- the need to present a united view on action proposals to government and other funders, over and above individual competitive research pitches
- the need to build durable collaborations beyond short-term project limits.

AOTEAROA NEW ZEALAND

[See the 'About Myrtle Rust' section of this report for key New Zealand web resources].

Beccy Ganley outlined the history of the New Zealand incursion of Myrtle Rust, which started in March 2017, initially on Raoul Island in the Kermadec Islands group (Rangitāhua), and then in May 2017 on North Island. It appears that all sites are likely to have been independent infection events; wind events capable of transmission of rust spores from Australia to NZ occur on average about 20 times per year.

The NZ incursion response, led by the Ministry for Primary Industries (MPI), included incidence reporting, delimiting surveys, removal of infected trees, tracing and restricting movement of risk goods, seed banking, research, and risk assessments. In April 2018, MPI made the decision to close the incursion response and move to long-term management. Australian assistance in this incursion phase was much appreciated.

Roanne Sutherland summarised the spread and current extent of the pathogen, noting that to date there has been a strong correlation between the pre-incursion risk-map and realised distribution. The NZ season for active Myrtle Rust is summer, November to June, with peak from December to April.

Aotearoa New Zealand has 38 native Myrtaceae taxa (28 described) across 6 genera: 10 *Kunzea* taxa (Kanuka and others), 2 *Leptospermum* (Manuka), 2 *Lophomyrtus* (Ramarama and Rohutu), 12 *Metrosideros* (Pōhutukawa, and other Rata species), 1 *Neomyrtus*, 1 *Syzygium* . The conservation status of all indigenous Myrtaceae was raised in 2018, in response to the potential for decline due to Myrtle Rust, to the umbrella Threatened category. Within this, 16 nominate species are now listed as Nationally Vulnerable, ten as Nationally Critical, and one as Nationally Endangered. New Zealand also has 200+ exotic Myrtaceae species, some important economically, and some naturalised.

No infection has been seen on the ten *Kunzea* (kānuka) species in the wild. In *Leptospermum* (mānuka), one species has been infected in the wild, as have both *Lophomyrtus* species, and several *Metrosideros*. The sole *Syzygium* (*S. maire*, Swamp Maire) has been severely impacted. 17 of the exotic Myrtaceae have been found to be hosts.

Lophomyrtus bullata (Ramarama or Bubbleleaf) is an important species of regenerating shrublands over a wide area, with edible fruits that are a traditional food. It is severely impacted, with foliage, flowers and fruits all susceptible; seed viability has been reduced. Myrtle Rust damage on new foliage is exacerbated by thrips damage on older foliage. *Lophomyrtus obcordata*, Rohutu, is also very susceptible, as are the fertile hybrids it makes with *L. bullata*.

Syzygium maire, which is not conventionally seed-bankable, blooms and fruits during peak Myrtle Rust season. *Syzygium maire* could be at greatest risk of localised extinction due to habitat loss, and in some areas functional extinction of populations.

Pōhutukawa (*Metrosideros excelsa*, known in Australia as New Zealand Christmas Tree) is culturally sacred to Māori and is an iconic landscape species around much of the North Island coast. An important coloniser of bare rock, and a coastline stabiliser, it is highly susceptible to Myrtle Rust infection on leaves, stems, flowers and fruits, and on epicormic shoots. Dieback is occurring.

Bartlett's Rātā (*Metrosideros bartlettii*) is known to be highly susceptible, but impacts in the wild have not been determined. Northern Rātā (*Metrosideros robusta*) is a tall forest tree which starts life as an epiphyte; its susceptibility in the wild is unknown. Southern Rātā (*Metrosideros umbellata*) is another widespread forest tree, and there are six species of Climbing Rātā – for all of these, susceptibility and impact are poorly known or unknown. Clearly much field assessment is needed.

Leptopspermum scoparium, mānuka, is economically important for honey production, and is susceptible to infection of leaves, stems, and fruit. Knowledge of infection and impact in the mānuka (Leptospermum) species, is variable.

Of the exotics, *Syzygium australe* is a significant ornamental species (also naturalised in places), and is very susceptible, with pruned hedges generating a high local inoculum load. It also has weedy attributes with long-lived well dispersed seeds often by birds and seedling are shade tolerant that can quickly establish in windfall gaps and forest edges.

Beccy then summarised the key research and management approaches. Government investment has focussed on science projects. The current phase of funding is coming to a close. Focus will now shift to maintaining some lines of investigation as ongoing research, and the transfer of results into management tools for communities and landowners. A refresh of the National Myrtle Rust Strategy is foreshadowed, along with scoping of further investment, potentially including germplasm collection and resistance breeding.

There is continuing high emphasis on improving biosecurity and phytosanitation in the nursery sector.

Research programs to date, and key New Zealand documents (not exhaustive):

- *Catalyst MBIE Fund* – targets international collaboration; in the Myrtle Rust space this has been a trans-Tasman collaboration.
- *MPI-led research* (2017-2019) – lots of surveillance, monitoring, rust genomics, social science, susceptibility testing; also epidemiology and host phenology, control options, breeding for resistance, and te ao Māori [respect for and incorporation of Māori perspectives]. Note that for Māori, all native trees are culturally considered tāonga [treasure, heritage].
- *Beyond Myrtle Rust* (https://www.landcareresearch.co.nz/discover-our-research/biodiversity-biosecurity/ecosystem-resilience/beyond-myrtle-rust/), is a research program with key areas including: understanding of *Austropuccinia psidii* reproduction in New Zealand; investigating broad scale impacts; investigating plant and ecosystem resistance; and developing Māori leadership capacity and strategies in the Myrtle Rust response.
- *Ngā Rākau Taketake – Saving our iconic trees from kauri dieback and myrtle rust* (https://bioheritage.nz/about-us/nga-rakau-taketake/) is a national program tasked to undertake urgent research into Myrtle Rust, housed in the Biological Heritage National Science Challenge. It focusses on research using traditional knowledge; mobilising communities; ecosystem impacts, including baseline data collection; integrated surveillance and management, and cultural control of data; the host–pathogen environment; and conservation and restoration, including seed storage biology and technology.
- *Myrtle Rust Science Stocktake*: https://bioheritage.nz/outputs/myrtle-rust-science-stocktake/, is a national inventory that includes New Zealand Myrtle Rust outputs since 2008.
- *Myrtle Rust Strategy 2019–23* (https://www.myrtlerust.org.nz/how-you-can-help/myrtle-rust-strategy/) and a supporting *Myrtle Rust Science Plan* (https://www.myrtlerust.org.nz/science-and-research/myrtle-rust-science-plan/) to guide implementation of the research aspects of the Strategy.

In the communications area, there are two key elements:

- *Myrtle Ora* open meetings community meetings every second month.
- The monthly Beyond Myrtle Rust webinar series (https://www.landcareresearch.co.nz/discover-our-research/biodiversity-biosecurity/ecosystem-resilience/beyond-myrtle-rust/webinar-series/)

For the plant nursery sector, *NZ Plant Pass*, a voluntary biosecurity standards scheme, has been launched. As at April 2023, it had 74 nurseries registered (the goal is 175).

New Zealand is approaching a funding cliff. *Ngā Rākau Taketake* ends in February 2024, and *Beyond Myrtle Rust* ends in June 2024. A general reform of New Zealand's science is underway, and future directions and funding possibilities for Myrtle Rust research, and for conservation actions, are unclear at this point. A refresh of the *Myrtle Rust Strategy* is planned, along with an update of the *Myrtle Rust Science Plan* that includes research gaps and priorities.

THEMATIC PRESENTATIONS, Days 1–3

Names against presentations below are those of presenters only. For co-authors, see Abstracts on the AMRC2023 pages of the ANPC's Myrtle Rust website https://www.anpc.asn.au/myrtle-rust/, or check the opening slides of each presentation on the conference video recordings (ANPC YouTube channel, https://www.youtube.com/playlist?list=PLuPMH5OJZz0ECW5mA5wyx2v8C4SZjTsco).

Day 1 Session 2: Fundamental science of the pathogen and host

Note*: Talks in the 'Fundamental Science' strand should be viewed in the context of considerable strides in the last five years in the genomics of the Myrtle Rust pathogen (e.g. McTaggart et al. 2018, doi:10.2144/btn-2018-0019; Tobias et al. 2020, https://DOI:10.1093/g3journal/jkaa015; Tobias et al. 2020, https://doi.org/10.1101/2020.03.18.996108; Edwards et al. 2022, preprint https://doi.org/10.1101/2022.04.22.489119); and the genomics of some exemplar Myrtaceae (e.g. Tobias et al. 2018, doi.org/10.1094/PHYTO-09-17-0298-R; Santos et al. 2020, https://doi.org/10.1007/s11103-020-01030-x; Yong et al. 2021, https://doi.org/10.1007/s11295-021-01511-0); Chakrabarty et al. 2023, https://doi.org/10.1007/s11295-023-01602-0), all adding to earlier genomic studies in the eucalypts, as well as to phenotypic studies in several genera.*

They should also be viewed in the light of the startlingly rapid development of the other '-omics' techniques, immensely powerful and now becoming routine in molecular circles, but still poorly known in some other sectors. These techniques, as demonstrated in the talks by Ashley Jones and Michelle Moffitt, give a wholly new level of insight into the translation of genetic instructions from DNA into RNA and then into *processes of protein synthesis and cellular control, including reactions to the reciprocal detection by host and pathogen and their subsequent chemical behaviour, which will over time illuminate the physiological interactions between host and pathogen during and following infection events.*

TALKS IN THIS SESSION:

- Perspectives on rust incursions (Prof. **Robert Park**, Univ. of Sydney)
- Working towards understanding host/pathogen interactions (**Peri Tobias**, Univ. of Sydney)
- Comparative genomics to decipher adaptation of the fungal pathogen *Austropuccinia psidii* to host species in the Myrtaceae family (**Thaís Boufleur**, University of São Paulo/Australian National University)
- Exploring post-transcriptional modifications during myrtle rust pathogen-plant interactions (**Ashley Jones**, Australian National Univ.)
- Transcript to protein: understanding the early pathology of the *Austropuccinia psidii*–mānuka interaction (**Rebekah Frampton**, Plant & Food Research, NZ)

Prof. Robert Park drew from research on the cereal rusts to illustrate general problems of rust pathogens, especially the impact of exotic incursions. Monitoring of these pathogens over the past 100+ years has shown clearly that Australia and New Zealand form a single epidemiological unit in terms of easy exchange of rust inoculum, whether natural or human-mediated. Incursions of exotic pathogens to the region were discussed; notwithstanding their adverse effects, these events have provided an opportunity to study continental-scale rust spread and evolution and have guided resistance breeding. Agricultural systems and pathogens are well suited to this research. He noted that Australia has had 15 incursions of exotic wheat rust variants in the last 100 years, and the frequency of incursions is going up steeply, and not just because of better detection – most of this increased incursion rate is believed to be via human vectors. Diagnosis of new incursions is greatly aided by whole-genome sequencing and the increasing availability and power of global wheat rust phylogenies. He notes that new incursions can bring in not just new virulence, and potentially affect a different host range, but may also bring other new traits and attributes – in cereal rusts, for example, fungicide insensitivity, or tolerance of higher temperatures. Hence repeat introductions of any one pathogen species or biotype may potentialise increased risk and damage in several ways, including by transfer of traits between strains. Long-term monitoring, national coordination and long-term commitment and funding are essential for both biosecurity and to inform resistance breeding programs. Renewal of the skills base is another issue of fundamental importance.

Peri Tobias gave an overview of recent work on host/pathogen interactions from the perspective of the University of Sydney myrtle rust research group via its collaborations, including with researchers in New Zealand, Brazil, and South Africa. [Several of these studies are the subject of later more detailed talks in this conference]. Genomics and transcriptomics allow an understanding of the basis of pathogenicity and resistance, differences across strains of the pathogen, and insight into pathogen population structure and observed changes in virulence. A revised genome for *Austropuccinia psidii* is has recently been published in preprint [Edwards *et al*. 2022, https://doi.org/10.1101/2022.04.22.489119]. A preprint has also just been published on the *Melaleuca quinquenervia* genome and its diversity in one class of resistance-associated genes, a potential model system [Chen *et al*., doi: https://doi.org/10.1101/2023.04.27.538497; see also Chen and Martino presentations below]. Studies are also in progress, with Louise Shuey and others, comparing genes from phenotypically varying plants (resistant vs susceptible) in several species. A complete phased genome for a susceptible phenotype of *Syzygium luehmannii* is underway (Tobias and others). Remote sentinel spore trapping is also being trialled [see Schwessinger presentation below]. The University of Sydney is also phenotyping naive hosts (e.g. 15 *Melaleuca* species from Western Australia – Martino and others). The breadth of collaborations built in the basic science area, including internationally, is truly impressive, but funding and the ability of individual researchers to remain consistently engaged are precarious.

Thaís Boufleur reviewed the multiple biotypes (strains) of *A. psidii*. Her talk posed the question of what genetic traits might be associated with the rapid global dissemination and establishment of the 'Pandemic' biotype, the most widely distributed strain globally and the only one currently in the south-west Pacific region. Selected Brazilian rust biotypes associated with Guava, Rose Apple, and *Eucalyptus* were partially sequenced, and phased chromosome-level assemblies performed bioinformatically and compared with the Pandemic strain. The Eucalyptus and Pandemic biotypes share a distinctive trait of unequal chromosome numbers in each of the two cell nuclei in the dikaryotic (urediniospore) life stage. All four biotypes differ in the size of the mitochondrial genome. A preliminary re-assessment of phylogeny suggests that notwithstanding these differences, all four biotypes should still be regarded as different strains of the same fungal species, but whole-genome 'sliding window' studies are planned to test this further. Future work will also look for significant differences in specific genes and the transposable elements that might be correlated with the apparent adaptive success of the Pandemic strain, particularly its wide host range, and whether other strains share such traits. The interim results are already being investigated for potential application in biosecurity detection and strain diagnosis [see poster for this conference by Luc Shepherd, and talk by Zhenyan Luo and Austin Bird].

Ashley Jones' work is focussed on the function of RNA transcribed from genetic code, the use of nanopore long-read sequencing as a means of more coherent interpretation of transcription, and detection of low-frequency protein isoforms. In the Myrtle Rust context, the project aims to create a reference transcriptome, to identify transcripts (in *Syzygium jambos*) that are expressions of a response to MR infection over time, and to look for any associated changes of transcript isoforms (variants of gene expression) or epitranscriptomic modifications to RNA such as methylation. Changing profiles of gene expression and isoform production are indeed observed in the days after infection, and methylation switching is evident, implying changes in the regulation of cell processes.

These cell behaviours are fundamental in the plant's response to infection, and to the pathogen's own 'strategy'. Further studies to link transcriptomically expressed plant defence behaviour back to specific genes, may enable targeting of the genes best for use or amplification in resistance breeding.

Rebekah Frampton presented on the downstream part of the infection response, the translation at different stages of infection of RNA transcripts by plant cells into proteins, and the complementary process in the pathogen. New Zealand's mānuka (*Leptospermum scoparium*) is the host subject, as there is a documented genome, and as a species it shows a useful range of phenotypic responses to infection (e.g. between stem and leaves, and within leaves), which are not necessarily derived from the same genetic mechanisms. There are some indications that leaf surface-architecture types may exist that are correlated with different resistance phenotypes, but this requires separate investigation.

Following infection, a number of pathogen effector proteins were detected coming into play as the pathogen progressively engaged with plant defence. Ongoing work will characterise the protein structure of the effectors, and determine what host-plant sites and processes these effectors interact with (early aspects of this work are presented in poster form at this conference by Jovarn Sullivan *et al*., and Nicky Hambrook *et al*.) Rebekah noted key points to emerge so far as: the challenges involved in working with non-clonal plants; the fact that in the early stages of infection (0–48 hours) deployment of the pathogen's suite of effector transcriptomic products appears to be independent of host plant phenotype; and that at least some of these putative effectors are likely to be pre-formed in the ungerminated spores and are necessary for the infection event itself.

Day 1 Session 3: Fundamental science of the pathogen and host (continued)

TALKS IN THIS SESSION:

- Solving a perennial problem: double-stranded RNA prevents and cures infection by myrtle rust (**Rebecca Degnan**, Univ. of Queensland)
- Double-stranded RNA as a sustainable control for myrtle rust (**Anne Sawyer**, Univ. of Queensland)
- Metabolomics identifies species-specific biomarkers of resistance to *Austropuccinia psidii* (**Michelle Moffit**, Western Sydney University

Rebecca Degnan discussed recent results using RNAi as an applied treatment for Myrtle Rust. Traditional chemical controls of rust fungi from agriculture and horticulture (e.g. fungicides) are not suitable for management of Myrtle Rust in many circumstances, for example in the wild. New control options are needed. RNAi (short for 'RNA interference') is potentially such a system.

RNAi is a post-transcriptional gene-silencing mechanism, in which fragments of 'interfering' RNA are tailored to match a gene essential to the functioning of a specific pathogen, and introduced to the system with a carrier molecule, to bind to specific function-critical sites and to block this critical process. The short *double-stranded RNAi* fragments used are highly specific to the target organism, with no likelihood of unintended effects; they are non-toxic, and non-GM. When applied externally, the treatment is known as 'exogenous' dsRNAi – it is taken up directly into the pathogen's cells. It can be used safely in the field or in cultivated situations, and can be paired with carrier adjuvants to prolong its persistence on the plant to some extent.

This is now demonstrated in a proof-of-concept paper (Degnan *et al*. 2022, https://doi.org/10.1111/mpp.13286) for the myrtle rust system, showing effectiveness in significantly reducing disease levels on treated plants. This technique can be used as both a short-term preventative treatment, and as a partial curative for established infection. Effects are not permanent, but curative effects have been tracked to the six-week mark. The technique is not a magic bullet, but could be an important component in ex situ conservation, industry (e.g. Lemon Myrtle production), some horticultural settings, and potentially even for limited deployment on particularly important individual trees or small populations in the wild. [In response to a question: commercial development is still some time off.]

Anne Sawyer outlined the history of double-stranded RNA (dsRNA) as a control mechanism, initially developed for viruses; it has also been trialled against some insects (Colorado Potato Beetle) and a few fungi (e.g. *Fusarium graminearum*, *Botrytis cinerea*). We now know [see Degnan presentation above] that *Austropuccinia psidii* urediniospores, the most common spore type for the pathogen, do effectively take up dsRNA when it is directly applied, and if specific essential fungal genes are targeted then infection levels and severity can be reduced. We are now looking at whether dsRNA can also provide more systemic protection, including by translocation within the plant. Mobility and persistence of applied dsRNA has been demonstrated within plants of *Arabidopsis* as a model system, with some gene knockdown seen in infecting root pathogens (*Verticillium dahliae* and *Fusarium oxysporum*). Can we use any of this for woody plants, and specifically Myrtaceae? Spray trials in this study have indicated dsRNA persistence on the outside of sprayed leaves (young and old), but no translocation within the plant. However, trials on avocado (which is not in the Myrtaceae) show that dsRNA can be delivered to leaves and roots via both foliar sprays and trunk injections, with persistence for at least six weeks. Back in Myrtaceae, petiole soaking with dsRNA does result in some uptake and translocation to new leaf growth. Further trials, including field trials, are pending.

Michelle Moffitt switched the focus from genes and their products to the downstream metabolic chemistry within the cells of healthy and infected plants, and the chemical dialogue between microbial pathogens and their plant hosts. Using metabolomics, we can track the response of the plant host to Myrtle Rust infection at the chemical level; we can determine if there is any specific chemistry that enables resistance by the plant; and we can determine whether we can use the presence or absence of these chemicals as biomarkers to guide resistance breeding of plants.

Untargeted metabolomics scans and measures a wide range of chemical molecules present in the plant sample at any one time (without chemically identifying them except to broad classes). Time-serial scans show changes in the chemicals expressed. The technique is already used in relation to other human and plant diseases.

The team found that Myrtle Rust infection triggers the generation of certain metabolites in *Melaleuca quinquenervia*. The initially strong response declines over c. five days, but it is expressed regardless of the eventual susceptibility phenotypes of the plants (at least on the metabolites profiled). This technique could thus be developed to detect early stage (up to 48 hrs) infection, even in the absence of external symptoms. The team then looked at chemical profile differences between susceptible and resistant plants *before* infection occurred. Chemical profiles correlated with eventual resistance phenotype were indeed found, implying that if we can identify the specific chemicals involved, their presence or absence could be used as a marker for that plant's resistance traits (or lack thereof), without exposing it to the pathogen. This could be of considerable utility in resistance breeding, and in assessing wild populations. Similar trials were then done on species from other Myrtaceous genera, to see if there were common patterns (there were) and common molecules involved (there were not – they appear to be species-specific). Many molecules were found to be specific to susceptible plants only, implying that we need to be open to the possibility of mechanisms that promote susceptibility, as well as those that promote resistance. Preliminary trials indicate that some of the metabolites of interest are stable enough to allow field sampling for analysis back in the lab. We need a robust protocol to metabolically phenotype plants and characterise unknown compounds.

Day 1 Session 4: Fundamental science of the pathogen and host (continued)

TALKS IN THIS SESSION:

- *Melalueca quinquenervia*; towards a model for myrtle rust Research (**Alyssa Martino**, Univ. of Sydney)
- Building knowledge infrastructure for the conservation of myrtle rust impacted species (**Stephanie Chen**, Univ. of New South Wales / Botanic Gardens of Sydney)
- Associated fungal diversity of the mid-storey tree *Lophomyrtus bullata* (**Mahajabeen Padamsee**, Manaaki Whenua Landcare Research)
- Breeding and genomics as a possible pathway for resistance to myrtle rust in New Zealand Myrtaceae (**Heidi Dungey**, Scion Research, NZ)
- Day 1 wrap-up and summary (**Angus Carnegie**, Dept of Primary Industries, NSW)

Alyssa Martino outlined her work on *Melaleuca quinquenervia*, a species of irreplaceable ecological importance for floodplains and freshwater wetlands in coastal eastern Australia. This species has advantages for study in that seed is available all year, is orthodox for storage, and can be easily propagated. The species shows variable response to Myrtle Rust infection, from extreme susceptibility to relative tolerance, and hence is a good subject for investigations into genetic resistance. A phased genome of *M. quinquenervia* has just been submitted for publication (a phased genome allows the disentanglement of genes and alleles inherited from each parent of the sampled plant – analysis of allelic variation is important in highly polymorphic gene families, some of which may be resistance-related). Part of the genome project was devoted to finding sets of resistance-related NLR genes, and a new pipeline technique for doing this across plant species was developed.

The next phase of work aims to establish a model system to identify genes and pathways involved in resistance to *A. psidii*, and to investigate whether these are common also to some other species of *Melaleuca*. Identification of the genes actually related to resistance requires transcriptomic analysis to capture gene expression differences between highly resistant versus highly susceptible hosts that have not previously been exposed to the MR pathogen (naïve hosts). Analysis of the resulting data is underway, but early indications are that there may be common molecular patterns for resistance vs susceptibility in naïve plants (but the influence of test plant relatedness has not yet been analysed). Shifts in gene expression differ significantly between haplotypes.

In parallel work, 13 Western Australian species of *Melaleuca* have been screened for susceptibility, and several have been found to have no resistance. The analytical techniques developed for *M. quinquenervia* will now be directed at some of these WA species to look for commonalities and differences.

Stephanie Chen talked about how we can use genomics in the conservation effort for Myrtle Rust-affected species. Genetic diversity is a key component of biodiversity; having good genetic information allows us to optimise conservation actions, to keep a species adaptable for the future. The present project, which should be seen in the context of Rossetto *et al*. 2021 (https://doi.org/10.1016/j.gecco.2021.e01492), develops Myrtle Rust case studies for *Rhodamnia rubescens*, *Rhodomyrtus psidioides*, and *Lenwebbia* sp. 'Main Range', which are among the best-sampled MR species to date. The aims are to describe the genetic structure and health of the species' survivors in the wild, to assess the representativeness of current ex situ conservation collections, and to determine the optimal selection of individuals for various cryopreservation scenarios. Stephanie drew attention to the need for taxonomic reality checks – for example, this study indicates that *Lenwebbia* sp. 'Main Range' is not decisively distinct genetically, and is part of a wider species complex, which should be managed as an entity.

Metacollections, in order to maximise the diversity captured and to enable informed breeding strategies, should be screened genomically to determine what elements are clonal, which is not always evident from field data. Representativeness of metacollections – how well they represent the genetic variability of wild populations – is vital to maximise future adaptive potential and breeding potential. All this data also helps to guide a prioritisation of lineages when it comes to more expensive and labour-intensive conservation actions such as tissue culture. Another factor in prioritisation is the presence or not of genuine rust-resistance traits; in this case, trial resistance screening has been conducted on *Rhodamnia rubescens*.

For Myrtle Rust-affected species in general, key tasks are to:

- establish a knowledge infrastructure on the current state of genetic variation across each species' distribution
- characterise Myrtle Rust resistance via controlled screening
- build a core germplasm collection for conservation use
- develop recommendations for conservation management and optimise populations to be adapted and adaptable.

The ReCER group at Botanic Gardens of Sydney is working its way through priority species as listed in the [Australian] *Myrtle Rust National Action Plan* of 2020, plus a few others. Many more species, along a spectrum of resistance, need similar attention. But we need to act quickly, before Myrtle Rust destroys the genetic diversity within these species.

Mahajabeen Padamsee presented another take on the fundamental science, outlining the previously undocumented fungal diversity of a single Myrtle Rust host species in Aotearoa New Zealand. The species is Ramarama (*Lophomyrtus bullata*), previously a common and widespread shrub or small tree, but now reduced and classed as 'Nationally Threatened – Critical' as a result of Myrtle Rust. Its ecology is poorly known, including the associated biota. Targeted surveys were conducted for macrofungi, and root samples taken from multiple sites for micro-fungi (assessed by Amplicon sequencing). Fungi of seven arbuscular mycorrhizal families were found to be associated with a huge diversity of Archeosporaceae, a fungal family not frequently found; the fifteen trees sampled represented the entire diversity of the family. Surprisingly, a relatively low diversity was found of the related Glomeraceae, which is common in the north of the country especially in Kauri areas. Fungal-associate species on *L. bullata* were common across different vegetation associations, although abundances differed. ITS sequences were used to profile other non-mycorrhizal endophytic root-associated fungi – there were many, across some 25 families. On aerial parts of the plants, 95 lichens were identified during field surveys; only 18 were previously known as *Lophomyrtus* associates [see also Prasad *et al*. 2022, https://doi.org/10.34074/pibs.00703 – ROM]. Further work is needed to determine if any of the fungal species encountered are only associated with *L. bullata*. There is clear potential for adverse change to these associated fungal communities as a result of *Lophomyrtus* decline. We also need to know whether mycoflora have any influence in resistance or susceptibility of the host plant to Myrtle Rust.

Heidi Dungey spoke on the potential uses of breeding and genomics in the particular context of Aotearoa New Zealand, where Māori cultural considerations are central. Tree breeding for conservation optimally uses quantitative genetic and genomic data to manage diversity in an active way. Marker-aided selection of host plant traits helps this, even in advance of a full understanding of what particular genes are doing. If sufficiently advanced, marker-aided selection can even mean that we can skip some field testing. Pedigree control can take us a long way. This is demonstrated for *Dothistroma* Needle Blight in Radiata pine, a major problem disease in NZ.

Marrying these insights to cultural co-design of tree breeding and restoration with Māori is a developing area. Scion Research is working with the NZ Dept of Conservation and Māori on a small restoration project, Te Rātā Whakamaru. Seedling trials over 2–3 years for Myrtle Rust resistance will provide field-based screening, using natural infection of seedlings and assessment of genetic variation to identify resistant plants. A longer-term conservation trial will then assess plantings in different culturally agreed areas, including areas of lower disease risk (e.g. in radiata pine forest), with the intent of having standing live tissue banks and seed production areas. Trial species will include *Lophomyrtus bullata*. Working with Māori is honouring the guardianship roles in what we are doing.

Heidi conveyed, with permission, a hapū (Māori sub-tribe/nation) perspective written by co-author Arapeta Tahana, Chair of the Rotoiti 15 board and key partner in this project. From his perspective, we are junior descendants of the natural ecosystem. Pathogens in the natural world are a physical representation of an imbalanced mauri (life force). When exploring the role of genetics in providing solutions to pathogens in the natural ecosystem, we need to consider:

- The links between the surrounding environment and the genetics of host and pathogen; some attributes only emerge and flourish within certain environments.
- Take time to understand the history, origins and evolution of the subject tree and pathogen, to find ecosystem solutions.

The hapū involved with this local project are supportive of selective breeding, but they advance the following points:

- Beware too much of a good thing. Don't overpopulate the environment with resistant strains, genetic diversity is a key ingredient for the natural evolution of species.
- Note the surrounding environs of selected strains and aim to replant in similar environments.
- Our hapū are not supportive of genetic engineering. We believe humanity is not yet conscious enough or capable of meddling with the DNA of the natural world.

Heidi concluded with a call for co-design to become a part of our standards of good practice and success.

Angus Carnegie summarised Day 1. Reflecting on First Nations perspectives offered by Aunty Joan Bell and Alby Marsh, and acknowledgements of Indigenous custodianship by others and Heidi's talk, it is time for all of us, including the new people, to step up for the protection of our lands, working in partnership.

Myrtle Rust can be seen as the point of genesis for Australia to really start thinking seriously about environmental biosecurity. Much remains to be done, both scientifically and in agitation, to build the Australian response to Myrtle Rust.

New Zealand's Myrtle Rust response has been impressive. On a back-of-envelope calculation in 2019, Australia had at that point spent about $2,000 ["$2" in video, in error] per Myrtaceae species, and New Zealand had spent about $0.5 million dollars [notional amounts, not directly spent *on* each species]. Nevertheless, the impending end of funding for the key New Zealand programs is a concern.

Angus cited Robert Park's outline of the development over a century of nationally coordinated wheat rust research investment, with the advantages of industry backing. Similar continuity and commitment is needed for Myrtle Rust. The various molecular talks today have all placed parts of the jigsaw on the board, and are beginning to add up to a route map for meaningful management. Potential novel management strategies, as exemplified by the dsRNA talks, are really interesting; there's a long way to go but these must be pursued.

The threat level to Western Australian species remains alarming, especially in view of the low levels of resistance in screened WA *Melaleuca* species. And Marj Padamsee's excursion into associated biota brings into sharp focus the need to assess the impacts of Myrtle Rust of whole assemblages of biota and their ecosystems.

A good day – we tend to harp on doom and gloom, but we have some good signs of progress.

POSTERS IN THE 'FUNDAMENTAL SCIENCE' STREAM WERE PRESENTED BY:

- **Sarah Sale,** Univ. of Canterbury, NZ, *et al*.: Getting rust fungi Lab-on-a-chip ready - growth in artificial environments on flat and heterogenous surfaces.
- **Nicky Hambrook**, Univ. of Canterbury, NZ, *et al*.: Defining the role of novel fungal effector protein AP5292 during myrtle rust infections to inform management of *Austropuccinia psidii*.
- **Eric Asare**, Edith Cowan University, Western Australia, *et al.: Austropuccinia psidii* in Western Australia: understanding its potential impact through epidemiology and host responses.
- **Jovarn Sullivan**, Univ. of Canterbury, NZ, *et al*.: Characterisation of a Novel Effector Protein from Myrtle Rust causing *Austropuccinia psidii*.

Day 2: Keynote Invited Speaker: Dr Richard Sniezko

(USDA Forest Service, Dorena Genetic Resource Center, Oregon USA)

NOTE: For full details of this information-dense talk, see recording at https://www.youtube.com/watch?v=AfOQUeSe9Qo&list=PLuPMH5OJZz0ECW5mA5wyx2v8C4SZjTsco&index=28 Also see Richard's July 2022 webinar at https://www.landcareresearch.co.nz/discover-our-research/biodiversity-biosecurity/ecosystem-resilience/beyond-myrtle-rust/webinar-series/

Developing disease resistant tree populations for restoration is, in principle, standard across species. There are however differences between a conservation approach and an agricultural or commercial forestry approach. The USDA's Dorena Genetic Resource Center services both approaches, and is very focussed on getting resistant trees back out into whichever situation is needed – it is not driven by any requirement for research output as such.

There is a continual need for education – of the public, business, and government – as to the values of healthy trees and forests, including non-market values. The non-market value of trees from carbon storage and air pollution removal, far exceeds the commercial value from wood products and food crops. Unfortunately, a majority of species face threats from climate change, many face increasing fire risk, and known pests and pathogens threaten 40% of total [global] woody biomass [citing Cavender-Bares *et al*., https://doi.org/10.1371/journal.pstr.0000010].

Resistance breeding programs may be the only remaining solution in cases where pathogen exclusion, control, natural resiliency, and silvicultural management do not work. Harnessing genetic resistance (and there is always *some* present, even if not strongly expressed) can make the difference in preventing extinction.

What will it take to develop a Myrtle Rust Resistance program?

- Passionate advocates for the affected species.
- A sense of urgency, but with a 10–15 year perspective.
- A review of other successful programs – don't reinvent the wheel.
- Proper structure and staffing of program, including dedicated technicians.
- Continuity of funding and personnel.
- A series of 5-year plans, and reviews/steering committee.
- External support and partnerships – a 'rust busters' group'?
- Don't prioritise research and publication except where needed to serve the restoration breeding program.

Considerations in Phase 1:

- Is there resistance in the species? Frequency of expression? Geographic distribution?
- What *type* of resistance - complete or partial? Major Gene Resistance (MGR) or Quantitative (QR)? MGR will tend to be outflanked eventually by evolving rust strains.
- What *level* of resistance (% survival and other metrics) is exhibited, or is needed? Is it durable and stable across time and environments? Is it heritable? Are there fitness costs?
- How will you establish your program (funding, infrastructure, staffing, continuity)?

Considerations in Phase 2 – developing resistant populations:

- Is breeding needed, or do selected resistant parent trees have enough R to enable immediate use of seed? How to protect resistant parent trees?
- What is the expected/desired percentage survival [and reproduction]? How many to plant?
- Key success factors:
  - Focus on developing resistant lineages, not on research within the program itself.
  - Do screening at large scale – must be reliable and correlated with field results.
  - Attend to infrastructure and personnel needs, and continuity of effort.
  - Ensure genetic diversity and adaptability are accommodated – Retain or mimic natural genetic variation.
- How to maximise restoration (develop reintroduction/augmentation strategies)?
- How can genomics, biotechnology etc. aid conventional resistance?
- Follow-through beyond first-found resistance; look for multi-layered resistance and possibly changeable effects through the life-history of the plant. An optimal genotype may involve mixed MGR and QR. Do not over-depend on one resistant parent plant.

Day 2 Session 1: Indigenous perspectives

SPEAKERS IN THIS SESSION:

- Queensland/New South Wales indigenous perspectives (**Tilly Davis** and **Aj Perkins**, NSW Dept of Planning and Environment)
- Indigenous responses to taonga impacted on by Myrtle Rust (**Alby Marsh**, BB3 Better Border Biosecurity, Aotearoa NZ)
- Significance of aka vines (*Metrosideros* spp.) to maaroi (**Hone Ropata**, Plant & Food, NZ)

Tilly Davis and Aj Perkins [pron. Ay-Jay] presented their views of Indigenous perspectives on Myrtle Rust in south-east Queensland and north-eastern New South Wales, and outlined a broader developing project on *Indigenous Forest Health and Environmental Biosecurity*. The project sits in the *Saving Our Species* program of the NSW Department of Planning and Environment, with support also from the ACEBO's office.

Aj pointed out that 50% of the Australian national reserve system is managed by Indigenous groups under the Commonwealth Indigenous Protected Areas program (as well as other lands returned through other legislation).

The current project is aimed at building awareness on-country of invasive threats, training Indigenous Ranger teams in both States, and building capacity for identifying and monitoring forest health threats, especially Phytophthora dieback and Myrtle Rust. This includes developing maps of threat risk analogous to existing fire history and fire use maps. Indigenous people also had a major role in the 2022 awareness video 'Myrtle Rust – the Silent Killer'. The First Nations response to Myrtle Rust is conditioned by culture. All the science and research going on is great, but there is very little input from First Nations people of this country. This disproportionate set-up needs to change.

Tilly spoke of the mass death of the once-dominant mid-story Myrtaceae in the Tallebudgera Valley forest study site in south-east Queensland, and the eerie quiet in spring now that the birds have to look elsewhere for food. The standing dead timber also provides a potential ladder for wildfire straight to the canopy. The effects of Myrtle Rust are not just on the affected plants – they are on other flora, on animals, on the land via erosion, and on people. The current project aims to combine Indigenous knowledge systems and western science to centre cultural custodianship in a collaborative relationship, extending this to the wider public. The future vision is for more partnerships with other First Nations communities, wider targeted biosecurity engagement, further capacity building for Indigenous Ranger teams through knowledge and skills transfer, and co-design of research and management.

Alby Marsh stated the role of Māori as *tangata whenua*, people of the land, and *kaitiaki* (guardians) of more than 1.5M hectares of freehold land in Aotearoa, 40% of it in productive use and 40% with natural vegetation. As kaitiaki, Māori have a responsibility as intergenerational land owners, to pass it on in a better state than when they received it; therefore this is a key driver for a sustainability ethos.

The Māori world view includes *taonga* (treasured heritage, human and natural); *wairuatanga* (the concept of a spiritual world, created life), and *atua* (the divine domain); *mana* (power and prestige); *mauri* (life force); *pūrakau* (instructive stories used to convey understanding of te ao Māori values); *whakapapa* (genealogy and relationships, including between people and with plants and animals); and *kaitiakitanga* (enhancement of the mana of the whenua, preservation of whakapapa, and maximising mauri).

The main priorities and knowledge of Māori in relation to Myrtle Rust relate not only to species but in some places to particular plants that mark relationships with ancestors. We have spoken with people of the land about what is significant to *them*. On the basis of this, we are responding to Myrtle Rust through awareness-raising, training, monitoring and surveillance, and one-on-one interviews with knowledge-holders and elders to guide activity and use of knowledge. These are Hāpu-led, community-led, solutions.

Much land-use results in monocultures. We have not yet looked enough at what constitutes a healthy ecosystem. What are the main contributors to ecosystem health or sickness? Does a diverse plant community have greater health? We should look at ecosystems within a matrix of the health spectrum factors and disturbance spectrum factors, recognising that a disturbed system is not necessarily unhealthy. This helps us look at cause and effect relationships: edge effects, humidity gradients, canopy cover, human or animal use in one area and not another. The book *Tiwaiwaka*, by Rob McGowan (Pa Ropata) is something of a guide to the way in which the land is the provider of all life, and situates a Māori view of ecology in a spiritual context.

Hone Ropata spoke on the cultural context of conservation in Aotearoa New Zealand, and of his MSc in progress. This is on *aka* vines, a suite of six forest canopy vine species in *Metrosideros* endemic to New Zealand and significant to Maaori as sources of fibre, food, medicine and a connection to pre-contact Maaori ontology.

Maaori culture spans a big area of the south Pacific, including Aotearoa New Zealand, the Cook Islands, Tuamotu, and Tahiti. In New Zealand, the Treaty of Waitangi, Te Tiriti o Waitangi, delineates what Maaori get and what they give up, in asking 'the crown' to govern. Article 2 guarantees that Maaori will retain possession over their treasured entities (taonga), whether these are lands, knowledge systems, artifacts, or indigenous flora and fauna – all the things that contribute to well-being.

Sociology is important in modern conservation efforts – it helps to direct our processes. The scientific method is a powerful tool, following the evidence wherever it leads, and telling us what we can do and how, but not *why*. That is determined by broader cultural values that must be kept in view. Research also has built-in directives that we need to be aware of.

POSTERS IN THE 'INDIGENOUS PERSPECTIVES' STRAND WERE PRESENTED BY:

- **Genavee Rhodes**, Univ. of Auckland, NZ, *et al*.: Developing culturally sensitive practices to investigate a taonga plant's physiological responses to drought and heatwaves.

Day 2 Session 2: Biosecurity

TALKS IN THIS SESSION:

- Lessons from Lord Howe Island: An opportunity for eradication (**Cristina Venables** and **Nicola Fuller**, Lord Howe Island Board, NSW)
- How to prepare for novel incursions? Using sexy genes to call lineages in the myrtle rust pathogen (**Zhenyan Luo** and **Austin Bird**, Australian National University)
- Pre-visual and early detection of myrtle rust on rose apple using hyperspectral measurements and thermal imagery (**Michael Bartlett**, Scion, NZ))
- Using spatial models to identify refugia and guide restoration as part of New Zealand's response to myrtle rust (**James McCarthy**, Manaaki Whenua – Landcare Research, NZ)
- Remote sentinel spore sampling (**Benjamin Schwessinger**, Australian National University)

Cristina Venables and **Nicola Fuller** shared lessons from the 2023 incursion of Myrtle Rust on Lord Howe Island (LHI), a World Heritage-listed oceanic island 700 km north-east of Sydney. LHI has five endemic Myrtaceae taxa, four of which are known from lab tests to be Myrtle Rust host species. LHI's preparation for Myrtle Rust started soon after the pathogen arrived in eastern Australia, with screening of four endemics (2011), and then on-island Myrtle Rust identification training, awareness activities, and development of a response plan (2012–15). In 2016 a first incursion was identified in the settlement area, on non-indigenous plants, and was successfully eradicated over several weeks – possibly the first successful eradication of this pathogen globally, and likely only achievable because of very early detection resulting from community vigilance.

In February 2023 a second incursion was detected by a leaseholder in the settlement area, again on non-indigenous ornamentals. Intensive searches were conducted, initially in the settlement. Awareness training of staff, residents and tour operators was again stepped up. Infected plants were treated immediately with fungicide, including a buffer area, and access restricted; new growth was removed and solarised and the plants then stem injected and killed. All removed trees were later replaced with non-myrtaceous fruit trees or natives. Later inspections extended into the Permanent Park Preserve (thankfully no infections). In all, 12,547 plants were inspected (556 person-days); 23 infected plants were found; 13 different species (603 plants) were fungicide-treated; 254 plants were killed and removed. The majority of infected plants were New Zealand Pōhutukawa (*Metrosideros*) and Bottlebrush (*Melaleuca* spp.). As in 2016, early detection was critical, as was rapid response to it, and community involvement. Precision mapping of planted Myrtaceae species across the settlement area helped immensely. The response was very labour-intensive, and the threat of future incursions will not go away. Further steps are being considered to improve biosecurity and further reduce the risk of arrival on goods or people, and to consider how to prepare for other plant pathogens.

It is now some months since the last observed infection. While continued monitoring is needed to confirm eradication, and while reinfection from outside is a continuing possibility, it appears that Lord Howe Island has now achieved eradication twice.

Zhenyan Luo and **Austin Bird** are investigating possible means to distinguish different isolates and strains of the pathogen. One line of investigation involves the pathogen's mating system. *Austropuccinia psidii* has a tetrapolar mating system. The urediniospore, the most common spore type, has two cell nuclei, Haplotypes A and B, with different 'mating type' genes; it may be possible to use allelic differences in the gene loci that determine these mating types, to distinguish between isolates.

Primers specific to *A. psidii* were developed, and the HD locus, which is highly variable between strains, was amplified and put through nanopore long-read sequencing. Similarly derived sequences from different isolates can then be compared phylogenetically, and related to area of origin. The technique is demonstrably able to distinguish between multiple strains of the pathogen, including samples derived from infected leaves and from air-samples containing spores.

The next stage will involve testing of mixed-DNA samples, further optimisation and validation of primers for a wider range of strains, and development of a PCR-based assay.

Michael Bartlett presented on the possible use of hyperspectral measurements and thermal imagery for the detection of Myrtle Rust infection before normal visual symptoms appear. Such a technique would be valuable in the nursery industry, where there tend to be large arrays of evenly aged and often genetically uniform material, kept under conditions that unfortunately are also suitable for the pathogen. Under the New Zealand *Biosecurity Act* 1999 it is not legal to move infected plants, so nursery managers need a diagnostic tool sensitive to early infection. At present, NZ nurseries are dependent on fungicides and/or visual surveillance. For pre-symptomatic assay, DNA-based techniques are possible, but are expensive and not failsafe. Hyperspectral and thermal imagery, as a possible alternative method, is based on the fact that plants contracting a disease exhibit changes in physiology and pigmentation which can be detected through changes in leaf temperature, or through changes in reflectance at different wavelengths. Rose Apple (*Syzygium jambos*) was used as the test species. Measurements were taken before inoculation with the pathogen and then at intervals over several days. Machine-learning techniques were used to classify observed indices. Findings included:

- A Myrtle Rust-associated reduction in canopy temperature, apparently due to cuticle damage which increases the transpiration rate (something also noted with other rusts and mildews).
- Thermal indices provided perfect classification (between infected or not) from one day *before* the development of visual symptoms.
- Narrow-band hyperspectral indices from older green leaves, which are not themselves directly affected by MR, were more accurate for classification than indices from the susceptible red leaves in this early pre-visual stage.

- Hyperspectral indices from red leaves became accurate for classification during early symptom development.

Sample sizes in this trial were quite small, and trials are also needed for other Myrtaceae species, and for application at whole-consignment scale. Other pathogens and stressors could also complicate real-world application. Nevertheless these results indicate potential for a robust detection methodology for use in a nursery setting. An early-access version of the accepted publication is at https://doi.org/10.1094/PHYTO-02-23-0078-R

James McCarthy is investigating modelling techniques for the identification of refugia from Myrtle Rust in New Zealand – essentially areas that are suitable for known host plant species within their natural range, but not suitable for the pathogen (or at least in which there is a low likelihood of infection). Presence/absence occurrence datasets for the plant can be used, in conjunction with other environmental variables, to produce host range maps and to delimit potential areas of relative unlikelihood of Myrtle Rust. Fifteen species have been modelled (McCarthy *et al*. 2021, https://doi.org/10.1111/1365-2664.13756). Two scenarios for Myrtle Rust refugia were modelled, to allow for uncertain likelihood-of-infection parameters. Even under the 'optimistic' scenario, refugium areas could be very small – in the case of the widespread Ramarama (*Lophomyrtus bullata*), only 2.5% of the patchy natural range was modelled as a potential refugium. However, some areas of land no longer supporting native forests and under other forms of land use, were identified as potentially functional refuge areas if ecologically restored. By contrast, the South Island species Southern Rātā (*Metrosideros umbellata*), which has only been recorded as infected in nurseries, has 90% of its range modelled as a refuge from Myrtle Rust under current climatic conditions.

The 15 species assessed had modelled refugium percentages ranging from 0.1% to 89.7%. This work should not be taken to diminish the importance of 'plants and place', but it can be used as part of risk and recovery strategy assessments. *How* to do so is a work in progress, although prioritising of extremely susceptible species for translocation, and targeted germplasm sampling and resistance screening, are among the likely measures. Improved data would allow refinement of these models. How climate change might affect the spatial parameters of disease suitability and refugial limits also needs analysis.

Benjamin Schwessinger spoke on behalf of a team working on the development of automated methods of sampling airborne spores, for molecular (DNA) identification. This detection strategy is of crucial importance for airborne agricultural pathogens, but is also relevant to Myrtle Rust. Applications include detection of spores in new (uninfected) areas, but also, potentially, the reading of spore-load variation in areas where a pathogen is established, and the early detection of new strains. Atmospheric parameters (temperature, humidity, etc) are captured at the same time as spore samples. Two diagnostic outputs are available, qPCR from existing techniques (highly accurate ID, but one species at a time), and now – an ANU addition – also metabarcoding, which allows identification of multiple species at a time of particular kingdoms or genera. Current trial sites are in Sydney and South Australia; a Canberra site is pending. Challenges now are to build models that relate qPCR quantification to metabarcoding outputs, and to go beyond species identification to be able to identify lineages (and hence likely geographic source), and to relate this to virulence prediction.

POSTERS IN THE 'BIOSECURITY' STRAND WERE PRESENTED BY:

- **Andrea Grant**, Scion, NZ: 'Gauging knowledge and information needs for diverse participation in long term responses to myrtle rust'
- **Luc Shepherd**, DPIRD WA/ANU, Australia, *et al.*: 'High-throughput identification and quantification of the air-borne fungal pathogen, *Austropuccinia psidii*'
- **Alyssa Martino**, University of Sydney, Australia, *et al*.: 'Gum Tree Guardians; A citizen science approach to monitoring the spread of myrtle rust in Australia'.

Day 2 Session 3: Environment and Ecology

TALKS IN THIS SESSION:

- WA Myrtle Rust Working Group update: A collaborative response to detection in the remote east Kimberley (**Mia Townsend**, Dieback Working Group, Western Australia)
- Myrtle rust infection of an endemic rain forest tree across a forest edge gradient in New Zealand (**James McCarthy**, Manaaki Whenua – Landcare Research, NZ)
- Impacts of myrtle rust induced tree mortality on nutrient cycling in a wet sclerophyll forest (**Kristy Stevenson**, PhD candidate, Univ. of Queensland)
- A versatile model for assessing climatic risk of myrtle rust (**Robert Beresford**, Plant & Food Research, NZ)
- Conservation and restoration of species impacted by myrtle rust: translating genetic data to actions (**Jason Bragg**, Botanic Gardens of Sydney, NSW)
- Seasonal progression of myrtle rust on *Lophomyrtus* trees in New Zealand leading to declining health and reproductive potential (**Michael Bartlett**, Scion, NZ)

Mia Townsend summarised the Western Australian response to the June 2022 detection of Myrtle Rust just inside the border of far north-eastern WA, the State's first incursion. WA is of particular conservation concern with respect to this pathogen, as it is Myrtaceae-rich (1568 taxa native), particularly in the far south-west of the State (1043 taxa), the area most likely to be suitable for Myrtle Rust establishment. The 2022 detection resulted from a targeted Myrtle Rust surveillance program, prompted by the proximity of the rust in the Northern Territory. The rust has to date been found at only one post-fire site, on two species of *Melaleuca* (*M. leucadendra*, *M. alsophila*). Limited but multiple pulses of infection have been observed, but no tree death to date. Repeat surveillance in the East Kimberley area (May-June 2023) has not found any further sites.

The response was advised by a multi-agency working group, with community, university and inter-State input (c. 15 partners all up). A collaborative response of this sort has advantages of mutual empowerment, broad expertise, and available human resources; it also has potential disadvantages, including what can look like a lack of clear leadership and fuzzy responsibilities, particularly in relation to funding.

For WA, a wind pathway for the arrival of Myrtle Rust in the south-west is highly unlikely; human or human-related vectors are the most likely pathway for introduction. Strategies include:

- Ongoing surveillance, involving sentinel sites and citizen science (the MyPest Reporter app); spore trapping is also possible.
- Preparedness: progress towards clear and pre-agreed rapid response plans and working arrangements between agencies; continued precautionary germplasm collection of selected at-risk species; and communication and capacity building (e.g. the TREEmendous Biosecurity Blitz of 2022, a month-long pest and disease observation drive).

More intensive training in the identification of Myrtle Rust was conducted in Queensland in early 2023 for a small number of personnel from three agencies and two other bodies, some of whom were involved in the later East Kimberley surveillance work.

'Green Card' training is a broad biosecurity and hygiene program led by the Dieback Working Group. The program is primarily directed at industry (utilities companies, contractors), but with wider applicability including Indigenous ranger programs. It is largely focussed on Phytophthora Dieback, but the 'arrive clean, leave clean' core is applicable to most biosecurity threats, and the program now has an embedded Myrtle Rust module.

Germplasm collection of at-risk species is ongoing; a short video outlining work by Kings Park & Botanic Garden is at https://www.youtube.com/watch?v=JqH8xlSSdjs (55 species to date).

Planned and potential actions:

- response planning for the south-west of the State
- a rigorous communications strategy
- lead time and investment for engagement and participation of Traditional Owner Groups
- continued guidance from the WA myrtle rust working group.

A strategic PhD project [Eric Asare, poster in the 'Fundanmental Science' strand of this conference] is looking at Myrtle Rust epidemiology in the drier climates of the north, the potential host range in WA, host resistance especially in *Agonis flexuosa*, and surveillance including host distribution and arrival pathways in the Perth area.

James McCarthy spoke on the ecological pattern of infection in the New Zealand endemic Ramarama (*Lophomyrtus bullata*) – anecdotal observations had suggested a possibility that infection of this species was more frequent along forest edges, but it was unclear whether this was observational bias. Clarification could help achieve better understanding of the rust's ecology and its interaction with Ramarama. Three plots/transects across forest edges, with arrays of temperature and humidity sensors, were used for serial observation from early 2021 to early 2023 (peak MR season). Analysis is continuing, but preliminary indications include:

- Leaf counts showed progressive loss of foliage.
- There is a complex relationship between Myrtle Rust infection, distance to forest edge, and canopy cover – a high canopy cover index seems to correlate with increased infection, although the immediately causal factors (e.g. temperature, humidity, light levels) have yet to be disentangled.
- Infection rates are higher for sub-plots with fewer large Ramarama trees.
- Infected neighbours mean higher infection rates overall (no surprise).

Kristy Stevenson is working on the only long-term monitoring site for Myrtle Rust in Australia, an area of wet sclerophyll forest with a rainforest mid-storey in the Tallebudgera Valley of south-east Queensland. She is looking at the effects on ecosystem function of the loss of species and large numbers of individual trees to the disease.

Functional attributes looked at include leaf traits (dry matter content, nitrogen content, carbon cycling), and dispersal and reproductive traits (fruit and seed attributes relating to trophic interactions, e.g. with birds). Dead trees represent c. 21% of the total estimated carbon stored in on-plot trees; this scales out to c. 18,190 kg/ha of carbon is stored in dead trees, now subject to much more rapid release than is the case for live trees. The standing mid-storey deadwood also represents an unusual fire risk in this wet sclerophyll/rainforest intergrade community, providing a fuel ladder that could easily carry wildfire into the canopy in the projected more-frequent dry years.

An initial paper from the study looks at the effects of MR-mediated mortality and floristic change on the traits of the replacement suite of species now emerging as dominant seedlings (Stevenson et al. 2023, https://doi.org/10.3390/plants12101970). The past predominantly bird-dispersal regime of the mid-storey species is unlikely to change, although a more or less prolonged reduction in fruit availability as the replacement suite matures could affect visitation patterns, and is almost certainly already doing so. A shift in dominant fruit type from multi-seeded Myrtaceae berries to single-seeded drupes could also affect visitation patterns.

The heavily impacted mid-storey species *Archirhodomyrtus beckleri* and *Rhodamnia rubescens* appear to have functioned as key colonisers in re-foresting of the site after past land clearance; the likely floristic replacements for these disappearing Myrtaceae, such as the native *Glochidion ferdinandi* or non-native weed species such as *Lantana camara*, may result in different forest dynamics.

Myrtle Rust has clearly affected the health and persistence of highly susceptible tree species in this forest type. It appears to be affecting some ecosystem properties and functions, cross-trophic interactions, resilience to future events, carbon storage, fire fuel loads, and to a lesser extent nutrient flux. Favourable rainfall seems to be maintaining the structural recovery of the community as forest, but with few individuals of the Myrtaceae species that were previously dominant.

Robert Beresford spoke on the Myrtle Rust Process Model, a tool directed at understanding the effects of weather and climate on the incidence, spread and management of MR in New Zealand. Likelihood-of-occurrence maps have been seen as a need since the incursion of 2017. Existing modelling tools (Climex, MaxEnt, Consensus, and Multi-model) all more-or-less agreed on North Island predictive range, but less so for South Island, and these correlative models were not suitable for the real-time predictions needed for operational decision-making (e.g. by crop and open-air nursery producers). Cereal rusts provide a useful analogy. For dispersal, rust spores need to be dry, and for germination and establishment they depend on wet leaf surfaces and low light, so the interplay of diurnal temperature and humidity, conditioned by transient weather conditions, all come into play. Accurate real-time modelling requires hourly data. A weather-based model seemed necessary, and one that would take account of variation in the latent period (the temperature-regulated interval between successful infection and the time when the first symptoms are likely to become apparent).

The Myrtle Rust Process Model (MRPM) has since 2017 been generating weekly risk maps, available through the www.myrtlerust.com website. Maps show, for regions based on the inquirer's nearest weather station, mean and maximum infection risk, sporulation risk, and latent period in days. The long-term average of maximum weekly infection risk from the model quite closely predicts the actual incidence of Myrtle Rust as it spreads southward. However, the model cannot yet take account of uncertain levels of susceptibility of some of the southern host species under natural conditions. The latent period/temperature model explains much of the seasonality of activity and spread of Myrtle Rust in New Zealand. The MRPM is also used to model optimal times for fungicide spraying of highly susceptible species in nurseries, depending on location, enabling optimisation of chemical use. The MRPM is also useful for modelling climate-based refugia for native hosts, and for climate change impact predictions. Further development will include infection intensity and latent period predictions for a wider range of host species, modelling seasonal leaf flush to define the most susceptible growth periods, and accounting for the effects of intense rainfall on spore production and infection. The model could be applied to at least some areas of Australia.

Jason Bragg presented on the genetic aspects of species recovery for *Rhodamnia rubescens*, now critically endangered across its range in NSW and Queensland. Emergency germplasm collections from surviving wild populations have been brought into an ex situ metacollection. Genetic analysis has shown that this metacollection is broadly representative of natural genetic diversity across the range (in NSW; Queensland samples will be incorporated). Importantly, it was also determined that this species is preferentially outcrossing, so detection of clones in the metacollection, and management of them for continued breeding system health, was a priority. Genetic insights are also essential to ensure that the bottlenecking effects that can result from wild decline and ex situ custody are identified and that genes and alleles loss is kept to a minimum in the process of selecting for resistance.

In initial assays for rust resistance of *R. rubescens* collections held at the Australian Botanic Gardens Mount Annan (ABGMA) and Booderee Botanic Gardens, conducted in collaboration with the Plant Breeding Institute of Sydney University, up to c. 30% of individuals showed resistance. These resistant individuals (whose parents varied from susceptible to resistant) have now been genotyped, and potentially we now may have the precursor set for a breeding population. Caution is needed to guard against some paternal individuals over-dominating the seedlings generated ex situ. Next steps will include 'challenge' trials in open cultivation without fungicidal protection, and beginning the process of selection. We also need to assess whether early resistance is sustained over the life of the plants.

Parallel work on *Melaleuca quinquenervia*, which is known to have very variable resistance, has involved seed collection across NSW, rearing of seedlings, and controlled rust exposure. Whole-genome data for 600 seedlings and 180 mother-trees is now available for analysis, which will allow insight into the mechanisms of resistance, and possible determination of markers that could be used to phenotype seedlings without the need for rust exposure trials – this would greatly aid restoration projects. 900 trees have been planted at ABGMA, deliberately skewed to progeny of families with a high proportion of resistance; this scale of planting with open pollination will elevate levels of diversity. Again, the continuity (or not) of resistance from seedling to adult, and its heritability, remains to be assessed, as does the optimal combination of different genetic forms of resistance.

Michael Bartlett and team have been tracking the seasonal progression of Myrtle Rust on the only two species of New Zealand's endemic genus *Lophomyrtus*. Both species, and their hybrids, are highly susceptible. Nine in-wild monitoring sites have been set up, and two planted sites, these last incorporating a number of other species. Data has so far been accumulated over three seasons for in-wild sites and two seasons for planted sites, mainly flush infection levels and resulting dieback. In the planted sites, not much infection on *Lophomyrtus* was seen in the first season (little new growth following planting). In the northern planted site near Auckland, two infection peaks are however evident (spring flush and autumn regrowth); at Rotorua (1–3° cooler), there is only one infection peak, in January. At the wild sites, infection incidence and severity were tracked. Foliage decline from first to second and third seasons was evident. In-field treatment with fungicide at one *L. obcordata* site was trialled, with quite good recovery of tree-sized individuals from severe dieback, including fruit production. The fruits of both species are highly susceptible to rust infection.

Similar seasonality observations in the wild sites came from maire tawake/Swamp Maire (*Syzygium maire*). Two climbing rātā species were also tracked, *Metrosideros diffusa* and *M. fulgens*, which commonly co-occur with *Lophomyrtus*. *M. fulgens* has usually mild symptoms, *M. diffusa* more severe. There is some evidence that inoculum load from the *Lophomyrtus* has a strong influence on infection levels in the co-occurring rātā.

Preliminary conclusions and off-plot observations suggest the likelihood of local extinctions of *Lophomyrtus* in some areas, but some wild trees remain anomalously healthy – whether escapes or real examples of resistance is yet to be determined. There is a clear need for prompt germplasm collection.

POSTERS IN THE 'ENVIRONMENT AND ECOLOGY' STRAND WERE PRESENTED BY:

- **Andrew Pugh**, Scion Research, NZ, *et al*.: Natural enemies of myrtle rust in Aotearoa New Zealand.
- **Vladislav Kholostiakov**, Manaaki Whenua - Landcare Research, NZ, *et al*.: The first investigation into the seed-borne microbial communities of *Metrosideros excelsa*.

Day 3: Conservation and Applied Science

- **Day 3 Keynote address: Roanne Sutherland** (NZ Department of Conservation): 'A conservation perspective of managing myrtle rust in Aotearoa New Zealand'.

OTHER PRESENTATIONS IN THIS SESSION:

- Conservation programs for two 'emergency' species (*Rhodamnia rubescens* and *Rhodomyrtus psidioides*) and projected other activity (**Craig Stehn**, Biodiversity and Conservation Division, Department of Environment and Planning, NSW)
- A pilot model for development of dispersed collections (metacollections) affected by Myrtle Rust. (**Amelia Martyn Yenson**, Australian Network for Plant Conservation Inc.)
- Saving Queensland's endangered Myrtaceae from myrtle rust (**Fiona Giblin**, Department of Agriculture and Fisheries, Qld)
- Seed banking options for conservation of species susceptible to myrtle rust (**Karen Sommerville**, Australian PlantBank, Botanic Gardens Of Sydney)
- Biotechnology offers an alternate conservation pathway for exceptional Myrtaceae species affected by myrtle rust (**Lyndle Hardstaff**, Curtin University)

Roanne Sutherland outlined the conservation perspectives for Aotearoa New Zealand. The country has 28 native species (38 taxa) of Myrtaceae. Taxonomic revision in progress in mānuka (*Leptospermum*) and kānuka (*Kunzea*) may modify these figures. The native ranges of 11 endemic host species fall entirely within the climatic suitability zone for Myrtle Rust, and these are at greatest risk of possible extinction. Myrtaceae are ecologically, culturally, and economically important. Myrtle Rust is additional to other threats to the family. Little is known about the biology and ecology of NZ's native Myrtaceae, including the associated biota, although one report details 109 species across 52 families of plants, fauna, and fungi associated with *Lophomyrtus*. [See also Padamsee's presentation at this conference, and Prasad *et al.* 2022, https://doi.org/10.34074/pibs.00703 – ROM.]

There are 83 confirmed Myrtle Rust locations on public conservation lands across NZ. Tree death is now being seen in Ramarama (*Lophomyrtus bullata*) on the East Cape after three years of infection; reduced fecundity is seen across *Lophomyrtus*; and across the family localised and functional extinctions are occurring for some species. Increased incidence and severity of infection on Pōhutukawa (*Metrosideros excelsa*) in the wet summer of 2022-23 is of particular concern.

Germplasm conservation should be a priority response. In 2017, the Department of Conservation (DoC) made 566 seed collections from 49 sub-regions of the country. These are stored in the New Zealand Indigenous Flora seed Bank (NZIFSB). Seed collection targets were not completed for all species and at present there is no active national germplasm collection program. Note also that *Syzygium maire* seed cannot be stored due to desiccation sensitivity. There are gaps in information on species distributions and within-species genetic structuring, that need to be filled to inform future collection strategies.

Monitoring and surveillance to obtain baseline data, disease incidence, severity and impacts are needed to support management actions; however, there is no national-scale surveillance and monitoring program. DoC has over the last summer set up an 8-site pilot set of plots (1 to 3 plots for each of eight species); two more sites are in prep.

Aotearoa's oldest (350+ years) Pōhutukawa tree, Te Waha Rerekohu, became infected in 2022-23, as have other old trees and Pōhutukawa forests.

There are over 8 million hectares of indigenous forests across NZ, facing a variety of biotic and abiotic stresses that must be addressed, additional to Myrtle Rust. Currently, tools for landscape-scale control and management of Myrtle Rust are lacking. Strategic science has been funded over operational science and management actions to date. There are overall funding limitations, as in Australia, and a lack of national coordination.

DoC has funded 193 'Jobs for Nature' projects as part of a Covid stimulus response – two of these are specific to Myrtle Rust. The Plant Pathogens team has provided Myrtle Rust training to over 300 DoC staff and 250 externals in the last two years, has created resources in English and in Te Ao Māori, and has developed best practice guidelines for field and domestic situations.

Priority needs are:

- National leadership and coordination for a conservation response.
- Funding for conservation science and management actions.
- Monitoring and surveillance to understand rust impacts and response options.

Craig Stehn described the NSW conservation-agency led emergency response for two species, *Rhodamnia rubescens* and *Rhodomyrtus psidioides*, under the NSW Government's flagship threatened species program, *Saving our Species* [see also related talks below by Martyn Yenson and Giblin, and elsewhere by Chen and Bragg]. SoS mainly addresses State-listed threatened species.

These two were the first species in Australia for which a direct relationship between Myrtle Rust and catastrophic decline was documented, in work by Carnegie and Pegg. The decline is through direct defoliation and death, drastically reduced fecundity of survivors, and loss of genetic diversity. Both species were formerly widespread in coastal NSW and Queensland, and both are now listed as Critically Endangered under NSW, Queensland, and Commonwealth legislation as a direct result of Myrtle Rust. The surviving cohort of plants in the wild is likely to be the last, pending conservation intervention. *Rhodomyrtus psidioides* now survives mainly as annually emergent suckers from the root systems of aerially dead adults; these manage limited growth before being defoliated by Myrtle Rust; the sucker fields are gradually declining. Older, multi-year survivors are now very rare, and usually in poor health.

Over the last four years the SoS project has focussed on:

- Rapid field assessments of rust impact on these species, and a few others.
- Collection of leaf samples for genomic studies to inform conservation actions.
- Developing a living ex situ collection incorporating as much genetic diversity as possible, as a prerequisite for resistance screening and possible selective breeding.

The project has involved diverse elements: recording infection incidence and severity in- and ex situ, spatial data, germplasm collection tracking, leaf samples for DNA, and other factors. A free app program, *Epicollect*, allows flexible construction of data input forms and has proved very suitable for both recording the in-wild collecting event, and ex situ monitoring. It has the advantage of not being proprietary software, and is easy to use.

The project has focussed on broadening the initially very small number of genetic lineages in protected ex situ cultivation. For *Rhodamnia rubescens*, prior to 2018 there were four secured NSW genotypes; there are now 35, from 21 wild populations, and a total of 283 individual plants to work with. For *Rhodomyrtus psidioides*, there were two NSW genotypes in 2018; there are now 60 genotypes from 30 populations, with 570 individual plants. Genomic analysis indicates that for both species we now have broadly representative material from across the range of both species, although the search for anomalously healthy wild plants must continue, as these may be the source of rare rust-resistance genes and alleles. Propagation and maintenance at current and the necessary future scales has significant costs and labour-time demands.

Future priorities include similar rescue actions for other rapid-decline species like *Decaspermum humile*, *Gossia hillii*, and *Archirhodomyrtus beckleri*, and assessment of ecosystem-level impacts. Beyond this is a perspective for ultimate success in getting more rust-tolerant plants back out into the wild, via resistance screening and breeding programs; initial funding to pursue this in NSW has been secured for a partnership with Botanic Gardens of Sydney. Closer engagement with First Nations groups in this process is also a priority. ‘Runs on the board’, which this project is generating, are critical for securing future funding.

Amelia Martyn Yenson outlined the first substantial Australian exercise in establishing a dispersed live-plant metacollection of a Myrtle Rust host species, as a risk minimisation measure and as a trial of lineage control and health monitoring across multiple sites. Ex situ (off site) germplasm collections may comprise seed, whole live plants, tissue culture, or cryostorage elements. An ex situ phase is commonly used in conservation actions for both common species (e.g. short-turnaround restoration seedbanks) and threatened species (e.g. to allow multiplication of numbers for translocation), as well as for as long-term precautionary conservation. For severely affected Myrtle Rust species, urgent ex situ germplasm capture and maintenance are essential, as wild populations are in rapid decline towards extinction. An off-site rescue phase is the only pathway for preservation of genetic diversity and the selection of rust-tolerant genotypes for eventual recovery actions.

Australia has a network of seed-banks; however, many Myrtle Rust-affected species have seeds that are not amenable to conventional banking methods. Also, arrays of living plants are needed to fill life-history knowledge gaps, screen for resistance, and produce seed. In 2021-23, the Australian Network for Plant Conservation led a Commonwealth-funded consortium project on Native Guava, *Rhodomyrtus psidioides*, in NSW and Queensland. The project conducted in situ (field) monitoring, expanded germplasm collections already held in a single large ex situ collection at one site (the Australian Botanic Garden Mount Annan), initiated ex situ collections at a second site (DAF Gympie), and bulked-up collections of all lineages. It utilised genetic techniques to check the genetic representativeness of material, and to identify priority lineages for protection.

Importantly, the project also piloted best practice in dispersing duplicate material to other premises, to minimise risks to the long-term maintenance of all these critical lineages (e.g., from disease, bushfire, other disasters). Dispersal to form a metacollection is also not without risks of human error and systems failure – careful attention to the health of these critical lineages is necessary, as is tracking of lineage information in a central database. The project assembled a consortium of five custodial partner institutions, all with a capacity to grow, protect, and track the health of the material. A strong risk checklist was used, alongside a plant sharing deed, training for all participating partner staff (horticultural, scientific, and administrative) in the goals of the project and in techniques for monitoring plant health and incident response, and workshopping of problems at frequent partner meetings. Very close attention was paid to maintaining the integrity of data and records held in different database platforms used by partners.

This project was a pilot that has established the feasibility of dispersed metacollections for Myrtle Rust species, and has navigated the problems. Another 20–40 species require this approach. We need to invest in nursery and botanic garden facilities, seedbanks, and the scientific horticulture workforce, and to continue to document workflow and data management procedures.

Project videos are at https://www.youtube.com/playlist?list=PLuPMH5OJZz0Efq2fJ-y2knJPv528nLTCu. A best-practice set of guidelines for ex situ plant conservation, including for non-seedbankable species, is at https://www.anpc.asn.au/plant-germplasm/ (Martyn Yenson *et al*. (eds), 2021).

Fiona Giblin addressed overlapping [see previous] work in Queensland, with an emphasis on germplasm collection of the same two species, expanding nursery stock as a precursor to resistance screening, and adding leaf samples to the NSW pool for genetic testing. Collecting has been from the Hervey Bay region south to the NSW border. Many sites known from herbarium records to have harboured these species now do not do so – even 2018 data is now often obsolete. *iNaturalist* and other sources are complementing those sources with post-2021 sightings; the reliability of such data for these species is improving as people get their eye in.

For Native Guava *Rhodomyrtus psidioides*, 86 propagation lines (cuttings, suckers) have been secured from c. 30 sites. No mature trees were seen. Myrtle Rust was observed at all but three sites. Leaf samples were taken from 96 plants, 10 from a single rust-free site at Jimboomba with plants up to c. 2 m tall.

For Scrub Turpentine *Rhodamnia rubescens*, fewer sites have been visited due to funding limitations. 24 propagation lines were taken, but difficulties in striking cutting material taken in warmer weather has reduced establishment success to only ten survivors; another round of winter collection is needed. 53 leaf samples were taken from 34 main sites; most sites had Myrtle Rust present; a few had surviving large trees.

A new project is about to launch, collaborative between DAF-Q and DES-Q, which will enable continuing collections and propagation of these and a number of other rust-affected species. Ten taxa are under consideration as highest priority (*Rhodomyrtus psidioides* and *R. pervagata*; *Rhodamnia rubescens*, *R. maideniana*, and *R. angustifolia*; *Gossia inophloia* and *G. hillii*; and *Lenwebbia prominens*, *L. lasioclada*, and *L*. sp. 'Main Range'. A further nine species form a second tier: *Eugenia reinwardtiana*, *Decaspermum humile*, *Gossia myrsinocarpa*, *G. fragrantissima*, *Rhodamnia sessiliflora*, *Archirhodomyrtus beckleri*, *Rhodomyrtus canescens*, *Rhodamnia dumicola*, and *R. spongiosa*.

Some species have some level of conservation plan already in place, with varying degrees of Myrtle Rust-related activity: *Rhodomyrtus psidioides* (germplasm collection and genetic analyses underway in NSW and Qld); *Rhodamnia rubescens* (ditto); *R. maideniana* (ditto); *Gossia gonoclada* (Logan City Council-managed); *Lenwebbia* sp. 'Blackall Range' (collections underway, Sunshine Coast Council); *Tristaniopsis exiliflora* (North Qld; student project plus NESP funding 2023); and *Syzygium hodgkinsoniae* (some genetic analysis undertaken).

Fiona reflected on the 12 years of Myrtle Rust in Queensland, lost opportunities (it is hard to quantify how many genotypes we have lost), and the continuing knowledge gaps for how species are faring in the wild. Time-lags for threatened species listings are a problem for making action happen.

Lyndle Hardstaff is engaged in a PhD project with Curtin University, based at the Australian PlantBank (NSW). Her work is in conjunction with the Rainforest Seed Conservation Project, including tissue culturing by Amanda Rollason.

Many species are classed as 'exceptional' in the sense that their seeds are not storable under conventional seed-banking conditions. This may result simply from a lack of viable seed (not or rarely produced, or inaccessible); from intolerance of one or more standard seedbank parameters, e.g. desiccation or freezing; or from deep dormancy which we do not yet know how to break. Many Myrtle-Rust-affected species are not conventionally storable, which means we need alternative conservation storage strategies. Biotechnology in this context means either *tissue culture* (TC, the growth of germplasm in artificial media, in sterile conditions), or *cryopreservation*, the storage of germplasm in liquid nitrogen (-196^{o}C) or nitrogen vapour (-130 to -192^{o}C). Both techniques are well established for agricultural species storage, but are a relatively new and still challenging frontier for wild species. Woody species in particular are hard to get into tissue culture successfully. PlantBank's trials of rainforest species started independently of Myrtle Rust, but as the threat has expanded more MR hosts have been taken on. Of 18 Myrtle Rust-susceptible species trialled, 15 have been successfully tissue cultured.

The tissue culture process is quite difficult and can be species specific. It starts with a choice of what material to use: seed, embryo, or cutting. The material then needs to be surface sterilised to prevent bacteria and fungi from overwhelming cultures – which may also mean the loss of mutualist species which would normally be beneficial to the plant. A suitable growth medium has to be formulated, with specific nutrient balances. And there is a lot of regular maintenance, with transfer to new medium every few weeks to months. The compensatory benefit is that once established, plant lines can be maintained for many years in sterile conditions, with good prospects for revival to full plant status and use, such as in translocation and restoration. In the meantime, it is available for use in genetic studies, and as source material for cryopreservation. Tissue culture buys us time, which is essential in the Myrtle Rust context.

Cryopreservation is likewise a demanding process. A precondition is that the material needs to be desiccated first, to avoid ice crystal damage at the cellular level. There are again pre-treatment steps: reduction of water content, and its replacement with cryoprotective agents that replace the water, help maintain cell turgor, and facilitate freezing without ice crystallisation (vitrification). Storage is then typically in liquid nitrogen. Material can be retrieved by careful warming, and growth resumes. Cryopreservation is a potentially good option for exceptional species when there are few or no other options, but this may also mean that there is little time and material to get the protocols right. At PlantBank to date, eight Myrtle Rust-affected species have been trialled, plus a variety of other species that may cast light on 'rust' species. Case studies include Lemon Myrtle *Backhousia citriodora* (only drier pre-treatments revived well), Native Guava *Rhodomyrtus psidioides* (12 different treatments, still under way), and *Syzygium paniculatum* (46 treatments; typically material survives but survival after re-warming remains problematic; work continues).

Day 3 Session 2: Conservation and Applied Science (continued)

TALKS IN THIS SESSION:

- Australian Government planning approaches to abating myrtle rust and other key threats to Australia's threatened species and ecological communities (**Ben Alter**, Threat Policy and Planning, Australian Government Department of Climate Change, Energy, the Environment and Water)
- Managing living collections in response to a biosecurity incursion (**Emma Simpkins**, Auckland Council, NZ)
- North Queensland impacts and prospects (**Darren Crayn**, Australian Tropical Herbarium / James Cook Univ., Qld)
- Developing cryopreservation for endangered *Gossia* - a genus of plants threatened by Myrtle Rust (**Jingyin Bao**, PhD candidate, Univ. of Queensland)
- Fighting Myrtle Rust with ex situ collections data (**Bradley Desmond**, Australian Seed Bank Partnership)

Ben Alter outlined Commonwealth responsibilities and processes under the *Environment Protection and Biodiversity Conservation Act* (1999). One area of legislative responsibility is to assess and list Key Threatening Processes (KTPs) that impinge on biodiversity. Listing recommendations to the Minister are made by the Threatened Species Scientific Committee (TSSC). Some 22 KTPs are currently listed. Myrtle Rust is deemed to fall under the Commonwealth's 2013 KTP listing of 'Novel Biota and their impact on Biodiversity' – it does not have a KTP listing of its own.

Follow-on actions to KTP listings may include statutory approaches (Threat Abatement Plan or TAP; negotiation of a State or Territory Plan; or a joint TAP with States or Territories). Non-statutory approaches include the development of a Threat Abatement Advice (TAA), or a National Action Plan. Any of these instruments may guide Commonwealth government investment.

The decision whether to develop a statutory Threat Abatement Plan hinges on criteria of feasibility, effectiveness, and efficiency. There is a statutory requirement for TAPs to be reviewed at least every five years. Implementation of TAPs or non-statutory equivalents is through combined efforts of various stakeholders and partners, not just the Commonwealth.

The *Myrtle Rust National Action Plan* [MRNAP, current 2020 version: https://www.anpc.asn.au/wp-content/uploads/2020/11/Myrtle-Rust-National-Action-Plan-2020.pdf] was developed initially through the Plant Biosecurity Cooperative Research Centre in collaboration with the National Environmental Science Program.

A National Myrtle Rust Working Group (NMRWG) was created under Commonwealth auspices in 2022, to continue the work of a previous informal working group. It has a dual purpose: to support implementation of the MR *National Action Plan*, and to update/amend some elements of the MRNAP to align it with the legislative requirements of a Threat Abatement Plan. The group is developing a communication strategy, and also serves to inform the Commonwealth, jurisdictions and other members of current knowledge and gaps.

Commonwealth investment and focus on Myrtle Rust is guided by its *Threatened Species Action Plan 2022–32* (https://www.dcceew.gov.au/environment/biodiversity/threatened/action-plan). This was published in the context of the 2020 Samuel Review of the EPBC Act, which signalled a need for its reform, and the release in December 2022 of the Commonwealth's response in the form of a *Nature Positive Plan* focussing on prevention of extinction, and faster responses (https://www.dcceew.gov.au/environment/epbc/publications/nature-positive-plan). As part of broader reforms to the EPBC Act – for which public consultation is planned to commence later in 2023 – there will be reforms to the threat abatement planning function, including development of a new threat typology to support a more consistent approach to identifying and describing threats. The Commonwealth TSSC is also assessing further Myrtle Rust-susceptible species for possible listing.

Emma Simpkins summarised some of the work developed over the last decade at Auckland Botanic Gardens, NZ, where she manages both in situ and ex situ actions. Auckland BG established a Myrtle Rust sentinel survey across the Gardens in 2014, before the 2017 advent of the rust in NZ; in the event the sentinel plants were not the first detections in the region. After Myrtle Rust became established, the focus shifted to monitoring its effects on native species. Auckland BG also has a role in working with mana whenua on conservation issues, including Myrtle Rust; this includes training for return of skills to iwi.

Taking on a highly threatened collection that required fungicidal protection in the face of Myrtle Rust posed challenges, including to Auckland BG's ethos of sustainable horticulture; previously fungicides and pesticides had not been used in the nursery. There is therefore a lot of hope for the development of more specific and non-toxic means of control. [Some of this adaptive work is presented in Stanley & Bodley 2020, Strings Attached: Managing ex situ plants highly susceptible to pathogens; *Australasian Plant Conservation* 29(2), https://search.informit.org/doi/10.3316/informit.499456813202503].

Auckland BG has also been instrumental in facilitating collaborative research on Myrtle Rust, and on wider issues of biosecurity and plant hygiene at the interface between horticultural practice and wild species management (e.g. Stanley & Dymond 2020, Reducing risk to wild ecosystems in nursery production; DOI https://10.24823/Sibbaldia.2020.283). Auckland BG has also played an important role in training various groups in seed collection and processing, and has developed a solid relationship with the Ngāti Kuri local Iwi Trust Board. Finally, botanic gardens are a key locus for communications with the public and with particular sectors of it with plant interests, including students – the botanic garden sector needs to make more use of this.

Darren Crayn presented on the situation in north-east Queensland, where there is increasing concern about Myrtle Rust impacts, especially in the very biodiverse Wet Tropics World Heritage Area. The Wet Tropics WHA ranks sixth globally among protected areas in terms of the irreplaceability of its species, and eighth on the basis of threatened species. It is the home of many ancient, endemic, and/or threatened plant species and lineages. In the WHA there are 123 Myrtaceae species across 31 genera, about 70% of Australia's rainforest Myrtaceae; of these, more than 60 species are endemic to the area, as are four genera; 17 of the species are already listed as Threatened.

The Wet Tropics Management Authority recognises Myrtle Rust as one of the three principal disease threats to the world heritage values of the area, along with Chytrid disease in frogs, and Phytophthora root rot in plants.

Our current level of knowledge of Myrtle Rust impacts in the Wet Tropics is not satisfactory. Only one systematic survey has been undertaken (Fensham, Radford-Smith and Collingwood, 2021), involving snapshot surveys on hundreds of sites in both north and south Queensland. They categorised significantly rust-impacted species into non-legislative X and Y categories, with X-category species likely to become extinct within one (plant) generation. North Queensland species in X include (* signifies North Queensland endemic): *Backhousia hughesii**, *Gossia hillii*, *Gossia lewisensis**, *Lenwebbia lasioclada*, *Rhodamnia arenaria**, *Rhodamnia spongiosa*, *Ristantia pachysperma**. Only one of these species is currently listed as threatened at either State or federal level.

A further 19 species were Y-categorised, defined as suffering "pervasive myrtle rust infection, but some individuals and populations exhibit sufficient resistance such that some populations may survive beyond a single generation".

Resources have not been sufficient to stand up a major effort in the north, but within current capacity the Australian Tropical Herbarium (ATH) has been working with the Queensland Department of Agriculture and Fisheries and others, to develop a focus on species of ecosystem-level significance. One of these is Kanuka Box *Tristaniopsis exiliflora*, which is a dominant plant on the banks of fast-flowing creeks that drain to the waters inshore of the Great Barrier Reef; its decline could increase erosion into the Reef lagoon. Dieback in this species is patchy, ranging from only moderate to severe – we need to know what is driving this.

There is considerable unfunded work happening, notably by Brandan Espe at James Cook University Townsville campus, where a major live-plant collection nucleus has been established, with 36+ MR-affected species from north of Mackay, including multiple genotypes of some.

ATH/JCU have built a collaborative partnership to support a 'Rustproofing the Rainforest' funding proposal, modelled on the in-progress Tropical Mountain Plant Science Project (TroMPS) for ex situ conservation of species at risk from climate change. The Rustproofing proposal is to build a functional ex situ conservation collection for Myrtle Rust-affected species, as a precursor to selecting resistant genotypes. While not successful yet in securing funding, it captures the strategic goals for a Myrtle Rust response in North Queensland. Complementary areas including training, Indigenous co-design, and liaison with land managers, restoration practitioners, and other collaborators are all being actively pursued.

Jingyin Bao presented PhD work in progress on preservation of germplasm of endangered *Gossia* species. There are 47 *Gossia* species, occurring in eastern Australia (20 species), the Papuasian region, and New Caledonia. Many are threatened by a variety of processes, not just Myrtle Rust. A majority are however susceptible to Myrtle Rust, and for some it is a critical threat. In the survey by Fensham *et al*. (2021) [see previous talk], four were classed as category X (extinction imminent within one generation), seven as category Y. Only two are listed as threatened under the Commonwealth EPBC Act.

This PhD project is focussed on tissue culture (TC) and cryopreservation techniques for *G. fragrantissima* and *G. gonoclada*. [For a general description of tissue culture and cryopreservation, see summary of talk by Hardstaff, above]. TC storage for *G. fragrantissima* has been initiated at the Australian PlantBank, and work in this [Bao] project is underway for *G. gonoclada* at the Mitter lab at the University of Queensland. Also in this project is the development of a droplet vitrification protocol for *Gossia*, initially for *G. fragrantissima*. Axillary buds and apical shoot tips have been trialled; revival problems are being addressed by trials of 'cold' pre-treatments, which is looking promising. Once this pre-cryo stage is optimised, the project will move on to study post-cryo survival and regrowth, and translation of the protocol to other *Gossia* species.

Bradley Desmond outlined a national stocktake of Myrtaceae germplasm holdings, conducted in 2022 by the Australian Seed Bank Partnership, the alliance of Australia's major conservation seed banks. Brad noted that the overall Myrtle Rust response taking shape in Australia has three critical elements: fundamental research, maintenance of biosecurity, and secure ex situ collections. ASBP and its parent bodies in the botanic gardens sector have been in a position to begin the process of inventory of Myrtaceae species already held in ex situ collections around the country, and the retrieval of associated data that helps to place their place and time of capture from the wild. The survey, which depended on voluntary response from the many institutions small and large who hold such collections, also served as something of an awareness-raiser for those not already in the Myrtle Rust space. Data compilation can be an onerous task, and in order not to deter participation the survey sought detailed information only on a short-list of Myrtaceae species, essentially the priority species listed in the *Myrtle Rust National Action Plan* (MRNAP) and the four Myrtaceae species listed in the Commonwealth's *Threatened Species Action Plan* (TSAP).

26 institutions provided data: botanic gardens (mainly the larger ones), seed banks, arboreta, and universities. Many other organisations lacked the capacity or staff-time to contribute, but the level of response achieved establishes something of a baseline inventory. Some basic information was also gathered on whether these institutions were actually dealing with or monitoring for Myrtle Rust in their living collections, and whether they are part of the national Plant Sentinel Network (just under half are).

Of the MRNAP species, a large proportion of each category have some level of representation in ex situ collections: Emergency category species, 4 of 5; Very High Priority species, 11 of 11; Medium Priority 23 out of 27, and Medium priority World Heritage Area flagship species 6 of 6. Those MRNAP species not held by any respondent were: **Lenwebbia* sp. 'Blackall Range' (Emergency); *Backhousia oligantha*, *Gossia lewisensis*, *Lithomyrtus retusa*, and *Rhodomyrtus pervagata*.

The survey was also designed to align with the four Myrtaceae listed in the TSAP (and the survey itself was an action for Myrtle Rust identified in that plan). All four of these species are held to some level in responding institutions.

Some general information on holdings of Myrtacae overall was secured, beyond the rust-related lists of species. Of the c. 2,735 myrtaceous taxa now recognised in the *Australian Plant Census*, 2,036 (74.4%) are represented by at least one collection among the responding institutions; 699 are not.

Actual levels of representation in ex situ collections vary greatly; there is no assumption that they are yet adequate for the task ahead, but they are a start. Some of the lessons learned:

- Optimise future survey timing to avoid spring!
- Allocate more time and resources to harmonise and analyse the data received; a dedicated data analyst would be advisable.
- Most institutions are not (yet) funded to make additional collections of the Myrtle Rust priority species.

Next steps include:

- Further data analysis, and production of a final report.
- Inform the 'towards recovery' theme of the Myrtle Rust National Action Plan (being updated – see Ben Alter talk above).
- Support implementation of the Commonwealth's Threatened Species Action Plan.
- Assist with future prioritisation of germplasm capture for Myrtle Rust-affected species.

[* In discussion, a conference participant was able to point to a known holding of *Lenwebbia* sp. 'Blackall Range' in a commercial nursery.]

Day 3 Session 3: Conservation and Applied Science (continued): Intro to Friday plenary workshop

INTRODUCTORY TALKS IN THIS SESSION:

- Strategic goals, needs, and options for resistance breeding and related ex situ work (**Richard Sniezko**, USDA Forest Service)
- The Australian perspective: facilities, expertise, and potential species (**Geoff Pegg**, Queensland Dept of Agriculture and Fisheries, and **Karen Sommerville**, Botanic Gardens of Sydney)
- The New Zealand perspective: facilities, expertise, and potential species (**Grant Smith**, Plant and Food Research, and **James McCarthy**, Manaaki Whenua – Landcare Research, NZ)

Richard Sniezko reflected on some of the practical issues we can expect to encounter once we begin selecting for rust-resistant plants. The presence of resistance can set you up, once susceptible trees are knocked out, for a second wave of potentially more virulent infection as the pathogen adapts to the situation. By selecting for resistant plants, you are also creating the conditions for selection of the rust. Therefore a question to ask is, when you have resistant trees, will that resistance be durable? Have you selected only for major gene resistance (MGR) which is more easily circumvented by genetic adaptation of the pathogen? Can you layer different forms of resistance? Remember also that resistance may not need to be total to meet your goal of species survival.

It is important to plan forward:

- Characterise the problem in ways meaningful for different stakeholders, including public, government, funders, scientists ...
- What is the goal of the program? Under current conditions? Under worst case scenario?
- Will the response and program be centralised? Avoid risks of duplication, non-communication.
- What tangible actions can be taken? What interim goals should be pursued *en route* to the ultimate goals? Research as such should not be a goal, it is a means to realise goals.
- How can others help? What disciplines can you bring to bear?
- Expand the network; make linkages, publicise success stories.
- Anticipate expertise shortfalls and training bottlenecks: for example, many people are now trained in genomics, but fewer and fewer in silviculture and tree breeding (see recent issue of Forests journal: https://www.mdpi.com/journal/forests/special_issues/Genomic_Breeding_Tree)
- Ensure early dialogue between researchers and practice people to minimise communication and goal gaps.
- Risks and consequences: in screening, in selection, in re-wilding?

- What would you do with $200,000? $2,000,000? $20,000,000? Develop feasibility plans and project outlines – be prepared to pitch them at short notice.
- Note the growing literature on trees and human health – look at this area for supporting arguments.

Richard also mentioned a coming invitational three-day Applied Resistance workshop in July 2023, which is expected to attract personnel from all tree resistance-breeding programs in the USA. Events of this sort facilitate exchange.

Geoff Pegg and **Karen Sommerville** provided a scan of some of the facilities and expertise available for screening and breeding in eastern Australia. Comprehensive surveys, taking in other organisations and tenures, need to be done. **Grant Smith** and **James McCarthy** presented a similar overview for Aotearoa New Zealand.

AUSTRALIA

Geoff Pegg outlined the capacities of the Queensland Department of Agriculture and Fisheries. DAF has modern facilities for screening and controlled inoculation in Brisbane, and glasshouse/shadehouse facilities in Gympie, Brisbane and Redlands. In Gympie it also has facilities for storage of orthodox seed. All these however require funds to maintain, and therefore to use. Queensland's DAF Forest Pathology unit has expertise in diagnostics, field science, and in the molecular area. There is tree breeding expertise in conjunction with the University of Sunshine Coast, but this is moving away from forestry into non-woody crops – expertise reinvestment is needed, as there is no-one coming up behind David Lee. The same applies to eroding technical expertise. DAF has some capacity in entomology, but connections with the Myrtle Rust effort are not yet very strong; note that some invertebrates can be closely involved in amplifying disease damage; conversely, others may be partly or wholly dependent on Myrtle Rust host plants and vulnerable to co-extinction. The Queensland Government owns multiple field sites that could be used for field trials (e.g. Traveston, Redlands, and Walkamin in North Queensland) – again, available but not free.

DAF has done screening trials for Myrtle Rust resistance in some species of *Eucalyptus* and *Corymbia*; these have been at glasshouse scale only, involving family and provenance assessment, mostly of plantation or other forestry species. In breeding for rust resistance, we will have to stay closely aware of interactions with native endemic diseases. In the eucalypts for example, resistance to Myrtle Rust has been found to be correlated with a susceptibility to some native pathogens (*Quambalaria* on *Corymbia*, and *Teratosphaeria* on *Eucalyptus globulus*); there were some individuals resistant to both Myrtle Rust and the native disease, but you have to be careful.

In recently completed PhD work by Emily Lancaster, a provenanced set of Lemon Myrtle *Backhousia citriodora* (11 provenances plus some 'unknown origin' clones) has been assessed for rust incidence and severity since 2015. All the tested germplasm is susceptible to infection by the Myrtle Rust pathogen, but there were significant differences in both incidence and severity between provenances, between sites, and in site/provenance interaction. The best performer overall was 'Silver Valley' provenance planted at Traveston.

Can we establish programs for On-Country storage and screening? For some areas under First Nations control, there is no willingness to have plants removed from country. We need to develop dialogue as to how on-country seed storage, screening, and growing might be done. On K'gari (Fraser Island, Qld), post-fire monitoring plots for *Melaleuca quinquenervia* have been established, with additional non-plot survey lines. There is also a need to think about how we might make plant populations in situ more resilient in relation to the disease.

Karen Sommerville outlined some of the resources in New South Wales, starting with people. In this State and elsewhere we have strong cohorts of people with experience and dedication in horticulture, genetics, ecology and pathology; some are already engaged in the Myrtle Rust space, but most are preoccupied elsewhere. We have an asset in the plants themselves: we have good collections of three of the most rust-threatened species; we have good information on genetic diversity and natural distribution for those same species, and are starting to accumulate information of susceptibility variance. We have good nursery facilities in the major botanic gardens around Australia, although these are constrained in overall space and labour capacity. Next, we have a strong network of seed banks, most of which also have expertise and facilities for studying seed storage and revival. Some facilities have a tissue culture capability. Potentially we have land for field trials, at botanic gardens, universities, and perhaps at some Department of Agriculture field stations. We have good information technology capabilities, including now some labour-saving apps – Craig Stehn has mentioned the Epicollect5 app, which is proving to be very versatile in Myrtle Rust work and can help standardise the inputs from dispersed sites. Finally, we have very good networks in research and information exchange: the Council of Heads of Australian Botanic Gardens CHABG; Botanic Gardens Australia New Zealand BGANZ; the Australian Seed Bank Partnership; the Australian Network for Plant Conservation; and various universities.

AOTEAROA NEW ZEALAND

Grant Smith opened with the point that the social context for conservation action in New Zealand differs from that in Australia. All the species are taonga, treasured species under Treaty, which has to be respected. A lot of work, like seed collection and storage, needs to be Iwi-led; there is an overall social dimension that needs much attention; and Māori are sometimes very concerned about movement of germplasm between rohe (regions).

On-shore facilities include:

- Plant and Food Research, Palmerston North: mānuka seed and germination.
- New Zealand Indigenous Seed Bank, Palmerston North (the association of any accession provenance data with the germplasm does not appear to be retained).
- Existing seed banks for agricultural and pastoral germplasm (Agresearch, Plant and Food).

There is expertise for Myrtaceae in NZ, in particular:

- Karin Van der Walt (Wellington City Council's Ōtari Native Botanic Garden)
- Jayanthi Nadarajan (Plant and Food Research, Palmerston North)
- Emma Simpkins (Auckland Council)
- Peter Heenan and Gary Houliston (Manaaki Whenua Landcare Research)
- Peter de Lange (Unitech).

Recent taxonomic revisionary work in kānuka (*Kunzea*) means the number of nominate Myrtaceae species indigenous to NZ has dropped from 28 to 19.

There are described resistance traits in mānuka (*Leptospermum*) and kānuka, although the vast bulk of mānuka and kānuka on the landscape are susceptible. A major challenge is that even those instances of resistance that are known are tissue-specific, and in one instance on separate chromosomes, so even if social permission is obtained for selective breeding, the biological challenges are substantial. Susceptibility and resistance also vary by provenance.

New Zealand also has a huge proportion (by species) of introduced plants – some 90% of plant species growing in New Zealand were introduced, a contrast to Australia. These introduced species include 150–200 species of Myrtaceae (e.g. Feijoa, Guava, *Eucalyptus*), some of them quite popular.

New Zealand is also concerned by the threat of other biotypes of *Austropuccinia psidii* – we know that Aotearoa indigenous species are susceptible to the South African biotype and at least one South American biotype (Uruguayan, of eucalypt origin) under experimental conditions.

New Zealand's *Biosecurity Act* is very specific in its provisions, and this can make new research on invasive species quite difficult, at least in terms of rapid response; for example, gaining 'approved' status for new facilities.

James McCarthy spoke to the importance of Myrtaceae in New Zealand ecosystems. On an index of 'ecological importance' value at plant family level, Myrtaceae ranks second (Jo *et al*. 2022, https://doi.org/10.1111/jvs.13106). The tribes of the family contributing to this importance are, in descending order, Leptospermeae, Metrosidereae, Myrteae, and Syzygieae. The first two are of great importance as colonisers and nectar sources for other biota, among other attributes. New Zealand's six climbing rātā species (*Metrosideros*) are highly unusual in a mainly shrub/tree family.

For resistance breeding, how do we prioritise? Considerations naturally include observed levels of infection, but also which species are spatially most exposed to the disease; phylogeny and evolutionary distinctiveness; and social importance. We must also preserve genetic diversity and ecological integrity via ecotypic variation; we want to promote species health on a multi-dimensional spectrum, as well as ecosystem health and resilience. There has been some progress in looking at genetic diversity in a number of species: *Kunzea ericoides* (*sensu lato*; kānuka); *Leptospermum scoparium* (mānuka); *Lophomyrtus bullata* (ramarama); and *Syzygium maire* (maire tawake).

Day 3: Plenary workshop: Conservation, research gaps and the way forward: notes from the discussion

The workshop opened with invited comments from **Aj Perkins** and **Tilly Davis** (Australia) and **Riki Nelson** (Aotearoa New Zealand) about working on Country. **Aj** cautioned that traditional law/lore in his Gumbaynggirr nation places custodial responsibility on Traditional Owners to look after things of the country, on country, both plants and animals. You don't take species off country, and you don't bring things onto country that are not of that country. Myrtle Rust itself is an example of moving species and breaking cultural law. This has come up in relation to Koala translocations recently, and having species moved to a country that's not theirs is against cultural protocol and cultural safety. The same can apply to removing plants from their country and then returning them with the risk of yet more unknowns coming in. **Tilly** noted (speaking for herself, not for Butchulla elders), that if you are a custodian of what is on your country you have to keep those things safe. People bring in plants from elsewhere to create gardens, and even in bush tucker gardens they include plants from elsewhere even though K'gari has its own bush tucker. That can bring problems. Lemon Myrtle *Backhousia* is not indigenous on K'gari, but it's grown there now, and it is a Myrtle Rust host. For projects like these, there needs to be real and careful consideration with the Traditional Owners about how to do things on-country. Honour the relationships and honour the place. Do things on-country rather than off-country, if possible.

Riki Nelson spoke about Scion's *Heathy Trees Healthy Future* program, involving collection of Kauri seed (*Agathis australis*) in the context of Kauri dieback. There were robust processes to determine who were the right manu whenua from whom to seek appropriate authority. Cultural authority agreements can be struck – sometimes there are good experiences, sometimes not. Māori want to know of scientists: are they going to treat trees or seeds with respect and come back with information? Strong relationships have been developed between some mana whenua and external stakeholders e.g. Scion, Plant and Food, Dept of Conservation. There are now successful templates for how seeds are to be taken care of. Keep your communication robust and consistent.

Abbey Brown (Ngati Kuri Trust Board, NZ) gave an iwi perspective from the far north of North Island. Myrtle Rust hasn't quite hit that area yet, but we are preparing. We take a strong stance when it comes to taonga. We have two very rare rātā species, and their whakapapa (genealogy) is linked to that of people. That genealogical history – where these plants come from – has been missing in this conference. On seedbanking – there should be more of these around the country so taonga can be looked after and won't be compromised by incursions in those areas.

Hone Ropata reflected on Tilly's sharing about bush tucker introductions. Indigenous people have a "we are this because of that" relationship with land and organisms. There is a "This is ours, don't touch it" vibe. Usually the answer to requests for removal of material is 'no', but there is a way around it. It takes a lot of effort to build relationships that can result in solutions, but it's worth it. Recognise First nations aspirations as well as your own.

Discussion then turned to other aspects. **Damien Vella** raised the issue of unintended consequences through mixing of provenances – e.g. some provenances have unique endophytes. Mixing can't be undone. Do we need some restraint, should it be a last resort? In response, **Bob Makinson** noted that provenance tracking to avoid inadvertent mixing of lineages now held ex situ, and the principle of maintaining ecological and genetic integrity, have been a feature of Australian practice and planning for the Myrtle Rust response.

Heidi Gungey from Scion (NZ) restated the need to put plants and ecosystem health as the goal at the centre of this. We have a lot of science and technical capability, and we need to bring people in from a different areas of expertise. In situations where we can't do breeding as we normally do, what does an alternative approach look like? We need to be open to reinventing current science with a co-design element, and be innovative so it's a win-win for everyone.

Richard Sniezko spoke on seed source and provenance. The US approach is to identify 'seed zones' on best available data, and generally you don't move material between seed zones. This now has overlays of climate change and landscape genomics. It's clear that both New Zealand and Australia have some history of tree breeding and some facilities too, but like much of the rest of the world over the last 20 or 30 years expertise and resources have diminished somewhat. It was good to hear what's out there, but Richard was not sure that he had heard what is really needed given the scope of this problem – do you maybe need to quadruple the scale of your resources?

Emma Simpkins from Auckland Botanic Garden noted the recent revision of the Australian *Germplasm Conservation Guidelines*. In New Zealand we need to take stock of what resources and tools are currently available for on-ground conservation. Mana whenua across the country have seed drums for conservation (the Millennium Seed Bank system). It is time for a stocktake of what has been achieved with this, where are the gaps, and what the next steps are.

Angela Verner put a Queensland perspective on take-home messages from this "fascinating and a little bit scary" conference. Queensland has >700 threatened plant species. A coordinated and collaborative approach, with extension of existing networks, is the only possible way to work. Queensland is developing a working group for a State Plan for Myrtle Rust in Queensland, with a lot of outreach. A huge area is the need for better engagement with First Nations and healing of country. As Richard has mentioned a few times, marketing and communications are also essential to convey the urgency of the situation – we are running out of time for some of these species.

Cathy Offord (Australian PlantBank) reflected on the last ten years, since we realised that we had a crisis. There has been a snowballing of support for addressing Myrtle Rust, as shown by the number of people and range of organisations represented at this conference. We have the technical capacity, in spite of the big goals ahead. But we also need to look at training and student projects, and those presented today are very encouraging. We need to think about the quantum of funding required for the number of species we need to deal with.

Beccy Ganley thought New Zealand's biggest challenge is national coordination. Grateful to Australia for their support. A fortunate situation to learn from your experiences – positive and negative. Re marketing and lobbying: we don't have long to get this in place. Maybe we need a social science approach to help this happen?

Maj Padamsee: We need success stories and to publicise them. We need coordinated messaging about what we need, and what are our main goals. We should prepare media material and share it among our community – tell people why you should support this effort.

Craig Stehn: New South Wales has a threatened species focus with our interest in this breeding work, and there is a subset of species, mostly the legislatively listed ones, that we are targeting. These may not always be the optimal species for breeding because of the decline they have already undergone. But what does success look like, say for *Rhodamnia rubescens*? Is restoration over one part of its range success? Is a small restored population a success? Or are we trying to restore across the whole range?

Roanne Sutherland: New Zealand has been focussing so much on the rust itself and its impacts that we have forgotten to really look after our species and understand them. We need to understand the associated taxa, and build resilient forests. Shift primary focus to plants, not rust.

Mia Townsend: It is encouraging for Western Australia to learn from the east coast and NZ. We need to learn about the strategic way to do things.

Amanda Shade: A question from a Western Australian perspective: we have almost 800 Myrtaceae in the south-west of WA, more than half of them endemic. If you were in our position, and knew it was coming, what would you focus on before infection arrived?

Karen Sommerville: WA is lucky in having a drier environment, and many of your species have orthodox seed that can be seed banked. You should try to bank multiple provenances for every species likely to be affected.

Beccy Ganley: Funding is the sticking point! Fund entire response to optimise management.

Angus Carnegie: Based on the eastern Australian experience of 2010 to 2103, make sure you've got political clout behind you, so that scientific decisions are enacted without political confusion or conflation. "We've found Myrtle Rust", the scientists say, "and history says you should smash it right now" – but if you're a government at the end of a political cycle, and have just spent lots of money on other pests or diseases or a pandemic, and there's confusion about whether this new problem falls under an environmental Deed or a plant Deed or whatever ... there's confusion and you ultimately do nothing. And your window of opportunity will be very, very narrow. So – find political champions now. Someone senior who stands behind the science that says we need to do something.

Roanne: If I could start again, I would collect baseline data now: understand the trees, their flowering, fruiting, recruitment, other associated species.

Emma Simpkins: Broaden our scope, from species and areas to how we market this to secure funding. Draw on the 7th Global Botanic Gardens Congress last year, and its emphasis on conservation horticulture – this joins together multiple disciplines. Advocate to politicians and influential people for funding.

Mia Townsend: It's tangential, but an interesting piece of legislation is coming in Western Australia,– a Biodiscovery Bill, which will bring together several threads: the genetics of species impacted by MR, tree breeding, and cultural custodianship. This will mandate that any commercial benefits or scientific credit that comes from research have to be shared with traditional custodians. It's an example of legislation that can help us work together more effectively.

Cathy Offord: Horticulturists will be key – we couldn't do this work without them. Conservation horticulture is a growing thing in modern botanic gardens (clear in the 7GBG Congress outcomes). They have the science and conservation expertise, and they have a public audience. How can they help? Donations, influence on industry, exerting positive influence to get together the resources we need for this work. But from a botanic gardens perspective, progress also stems from having professional horticulturists, trained in techniques important to plant conservation. Guidelines exist [ANPC *Germplasm Conservation Guidelines*], and have been revised every 12 years. Conservation horticulture is a key discipline that meshes with other techniques required to deal with Myrtle Rust in the future.

Chantelle Doyle: Something that hasn't been discussed much here is funding. From my background in ecological consulting – is there scope for an ecosystem health and Myrtle Rust levy on developments, or as part of offset agreements?

Craig Stehn: New South Wales is working on something like this. The NSW environment agency gets a lot of survey records of MR-affected species from consultants doing BAM [offset] assessments. If a listed MR-affected species is going to be impacted by a development, then a payment goes into the general offsets scheme. There is work in progress to try to have MR-affected species dealt with differently – there are ancillary rules under the legislation that allow, if there is an impact, for payments into a conservation project for the species, instead of the general offset pool. This could be a better outcome. This approach has been used for one development, the Coffs Harbour highway bypass– the planning team were able to negotiate the offset payment going into a conservation project that is now driving resistance screening work for *Rhodamnia rubescens*. And it can carry money over from year to year.

Angus Carnegie: Can we get major corporates like Alcoa on board? Do we need to be talking to big companies who need to be spending money on something – could it be Myrtle Rust? Needs a concerted effort from someone who knows the ropes.

Bob Makinson: There are a couple of options there. Approach company with a specific project relating to local circumstances or current issue – but that then can be constrained by what they want you to do for their own visibility goals, and can enmesh you in specific disputes. Another way might be to establish a Myrtle Rust Foundation or Trust, which could have government or private/ public input with adequate kudos for donors, but more arm's length freedom of action. Either might be viable.

Vladislav Kholostiakov: Education through schools and society is important. Ask people about Myrtle Rust, people don't know about it. But if they can see a David Attenborough, a TV host, speaking about it, then it is more likely to be picked up by a teacher speaking about it as a global issue. People are more interested in animals, sure. But can we design lessons for schools and maybe a movie with a well-known host?

After closing remarks from conference convenor Peri Tobias, the session closed.

Myrtle Rust on *Rhodamnia rubescens*. Photo: Julie Percival

Post conference workshop

26–27 June 2023

Conservation strategies for the species worst-affected by Myrtle Rust, via screening and selective breeding for resistance, and eventual reintroduction.

This two-day workshop, adjunct to the conference, was arranged as a more tightly focussed 'working' (rather than presentational) event, and smaller attendance than at the main conference was envisaged. It was aimed at sharing knowledge and perspective across the Myrtle Rust community of concern of resistance breeding as a strategy for species recovery in the wild.

The workshop was hosted by Botanic Gardens of Sydney at the Royal Botanic Garden in central Sydney. We are grateful for the support extended by that organisation, and in particular for the active help of Damian Wrigley (Manager, Living Collections and Conservation) and Joel Cohen (Senior Living Collection and Records Officer).

The workshop was advertised to all registrants at AMRC2023 (many attended), and to an extra list of targeted stakeholders and experts. Attendance required a prior expression of interest; no fee was charged. The workshop was in plenary workshop format, with both in-person and virtual Zoom attendance. Approximately 45 people attended the workshop days.

Designated contacts for the workshop were Craig Stehn (NSW Department of Environment and Planning, Saving Our Species Program), and Bob Makinson (Australian Network for Plant Conservation Inc.). Scribe for the two days was Damien Wrigley, and IT wrangler was Joel Cohen (both of Botanic Gardens of Sydney). Notes below are based on records of discussion, with some editing and reworking by Makinson. There was considerable repetition of some points in the discussions, reflecting their cross-cutting importance; accordingly, much of this repetition has been retained in the edited notes below.

A key aspect of both the AMRC2023 conference, and particularly of this workshop, was the invited and funded attendance of Dr Richard Sniezko, Forest Geneticist with the United States Department of Agriculture's Forest Service, based at the Dorena Genetic Resource Center in Oregon USA. Dr Sniezko is a globally leading practitioner of tree breeding for disease resistance, with a long history of working with both commercial and non-commercial species, including several that are close conceptual analogues for the Australasian species at risk.

Background

The focus of the workshop was tree breeding for disease (Myrtle Rust) resistance in the context of a conservation program. This is an area of conservation poorly developed so far in Australia and New Zealand, although similarly conceived programs have been proposed or do run for some animal species in Australia, e.g. Tasmanian Devils, some chytrid-affected frog species, and selection/rewilding programs for warming-tolerant Great Barrier Reef coral species. Like these, selective breeding of plant species is a highly interventionist conservation technique that ideally we would prefer not to have to resort to. However, the simple fact is that in the face of acute pathogen threats, this technique is sometimes the only option, other than allowing extinctions by neglect.

For optimal effectiveness, this type of response to a disease-class threatening process, especially when effectively starting from scratch, should be *highly interdisciplinary* at the technical level, drawing on silvicultural, genetic, ecological, scientific horticulture, and botanical skill sets, and *pro-active in social engagement* especially in relation to First Nations interests and involvement, but also in terms of general social license and support.

Overseas examples of this conservation also affirm the need for a sustained and directed approach, as distinct from short-cycle funding based only on competitive open-call grants; the focus should also be on species survival outcomes over publications.

Disease-resistance breeding is of course well established globally in the agricultural context. In agriculture, the plant subjects are often non-woody species, and the desired result is often uniform plants with a narrow genetic base. In the conservation context, the desired result is very different – maintenance of original wild-type genetic diversity, and uniformity only in terms of a significant improvement in ability to survive the disease threat.

In Aotearoa New Zealand, resistance breeding as a potential strategy for Myrtle Rust response is still very much in the evaluation stage. Whether it becomes part of the toolkit, or a major focus, will likely depend on:

- the progress of the disease and the degree to which it threatens indigenous New Zealand plants
- cultural and social permissions, which if granted will shape the practice.

In Australia, the resistance-breeding approach to conservation of severely Myrtle Rust-affected species has been a focus of thinking since the publication of the *Draft National Action Plan for Myrtle Rust* in 2018, and was reaffirmed in the succeeding *Myrtle Rust in Australia – a National Action Plan* (2020). The approach is predicated on:

- large-scale germplasm capture, conserved ex situ under protected conditions
- screening of this ex situ material for resistance traits and genotypes
- continued searches for surviving wild plants showing putative rust resistance
- selective breeding for resistant/rust-tolerant genotypes, while maintaining overall genetic diversity and fidelity to locality-related genetics
- controlled 're-wilding' of more rust-tolerant genotypes to original localities, either as reinforcement for surviving populations, or as reintroductions where species have become locally or totally extinct.

This conceptual approach faces a number of challenges:

- To address the number of species seriously affected by Myrtle Rust in Australia (currently estimated as 30-50 species requiring intervention, all of which are woody species), it must necessarily be a medium- to long-term program, at large scale.
- While there is now a fair degree of consensus in the engaged science and conservation circles that resistance breeding and re-wilding is technically feasible, and that other alternative conservation strategies are lacking, there is not yet anywhere near an adequate level of engagement with First Nations to discuss the approach and its application in practice.
- There is not yet adequate awareness in higher levels of bureaucracy and government on the need for a cross-jurisdictional, cross-departmental, and coordinated and well-resourced approach with continuity over decadal-plus time frames.
- The dominant funding approach available at present, competitive grants with short delivery time frames, and often with a primary focus on research, is counter-productive for a situation needing sustained, directed funding (compare most agricultural incursion and breeding programs).

The goals of this workshop were to develop

a. A common understanding among Australasian Myrtle Rust practitioners of global experience in disease resistance breeding programs (RBPs) in woody plants, especially for rusts, and what promotes success.

b. A common understanding how conservation-oriented RBPs differ from those for commercial crop and timber species, e.g. in width of genetic base, maintenance of ecological fidelity and variation, social and cultural permissions.

c. An overview of the bureaucratic and social landscapes (Australia and NZ) within which an RBP model must develop.

d. An overview of existing expertise and facilities, government and non-government, that should be investigated in more detail for RBP involvement.

e. Consensus on a flexible and adaptive conceptual architecture for an RBP meta-program in the A/NZ context, noting that in Australia's case up to 50 or so species may be eventual candidates for inclusion.

f. Priority directions for scoping studies, information assembly, communications, and concept promotion in pursuit of integrated RBP in the two countries.

g. Ways of strengthening the collaborative approach both within-country and across the Australasian region.

No fixed assumptions

Registrants were assured that no hard assumptions would be drawn from the discussion about levels of commitment by potential partner organisations. Participants were asked to express informed views and ideas, not organisational commitments unless these are already in place.

This discussion was not aimed at development of any specific funding proposal, although we were hopeful that:

a. proposals for funding some elements of an overall RBP response will follow from the conference and the associated post-conference workshop, and
b. this can be done in a highly collaborative way that:
   - for Australia: dovetails with the *National Action Plan for Myrtle Rust* (2020)
   - for New Zealand Aotearoa: helps channel research and communication lessons since 2017 into a new action synthesis beyond the coming funding cliff.

Background resources

It was recognised during the preparation phase for AMRC2023 that many of the people we are seeking to reach, as potential participants in this work, have limited prior familiarity with the international examples that may prove fruitful for Australia. A package of materials to assist with the workshop discussion were made available to conference and workshop participants in the weeks leading up to the event, and remain available at a closed webpage: https://www.anpc.asn.au/myrtle-rust/amrc2023-sniezko-workshops/, password AMRC2023.

This material comprises:

- A link to a webinar video by Dr Richard Sniezko, part of the New Zealand 'Beyond Myrtle Rust' webinar series.
- 42 scientific papers or book chapters, as PDFs or links, covering exemplar projects and conceptual issues, mainly but not exclusively from North America.

These resources were flagged as not remotely exhaustive, and other suggested content was invited.

Workshop agenda and discussion points

DAY 1, 26 JUNE

Times	Sessions
9:30 – 10:45	Goals of a resistance breeding program: Introduction by Richard Sniezko (USDA)
11:00 – 12:00	Practical workflow for resistance breeding • Establishing need • Understanding resistance • Understanding reproductive biology • Determining scale • Designing breeding program • Estimating space, labour, facilities required • Estimating costs
1:00 – 2:30	Case study: *Rhodamnia rubescens* • Species biology and ecology • Work done to date and conclusions drawn. • How would morning 'workflow' session outcomes apply to *Rhodamnia rubescens*?
2:45 – 4:00	What expertise do we need? • Establishing disease resistance – (plant pathology, silvicultural, specialist horticultural skills, horticultural science, genetics, ecology) • Project delivery – (coordination, promotion, specialist fundraising).

DAY 2, 27 JUNE

Times	Sessions
11:00 – 12:00	What facilities/materials do we need? • Physical assets – built facilities (for screening and propagation areas, maintenance e.g. shade houses, and disease management). • Tenure – land for built facilities, field trial sites. Costs? Security of tenure? • Program architecture • Consumables
1:00 – 4:00	Species priorities constraints and opportunities • Resistance with observed resistance in the field • Species we have expertise in • Listed threatened species • Species prioritised through funding programs • Species with commercial interest • Availability of material and ease of propagation • Species suitably for field trial sites

Opening talk: Dr Richard Sniezko

How to be successful

- Establish the feasibility of the approach as a conservation tool (demonstrated success)
- Stress and secure continuity of resources and effort over a significant period of time
- Focus on operational outcomes

On the road to success - two US case studies, among others

- **Port Orford cedar – selected resistance to the pathogen *Phytophthora lateralis***

  Strategy followed:

  1) Select/breed for resistance
  2) Maintain genetic diversity
  3) Use adapted seed sources

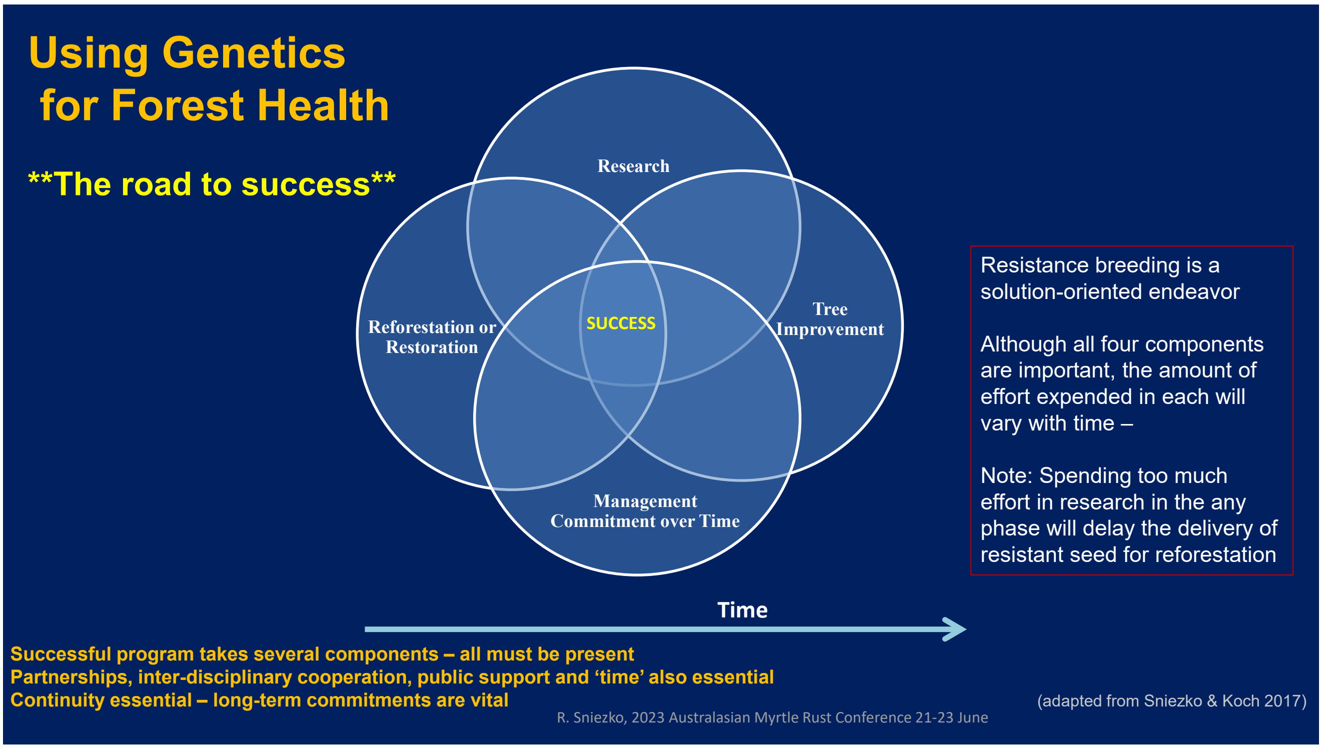
  Outcome: On the IUCN Red List of Threatened Species, the status of Port-Orford-cedar, listed as 'vulnerable' in 2000, has been downgraded to 'near threatened' as of 2013, with anticipation of listing as a species of 'least concern' within 10 years, if conservation actions, including planting resistant seedlings, are successful and maintained (Farjon 2013).

- **Whitebark Pine Restoration Planting at Crater Lake National Park (since 2005)**
  Strategy followed: Dual purpose: a species/ecosystem restoration, and a genetic resistance validation trial. Also a showcase for public outreach and conservation education.
  References supplied, see *Resistance Breeding – Issues and Resources* page at https://www.anpc.asn.au/myrtle-rust/. Outcome: on-going.

What will it take to build a successful program?

- Some people passionate about the affected species
- Public support. Form a 'Rustbusters' group?
- Sense of urgency
- Review of other successful resistance programs; don't re-invent the wheel
- Proper structure and staffing of program; continuity of funding and personnel
- Series of 5-year plans and reviews (or robust steering committee)
- Some dedicated technicians

Preconditions for success



Genetic Resistance: Phase I Considerations – securing baseline information

- Is there genetic resistance at a usable level? Note that Resistance ≠ 'Immunity'.
- What is the frequency and geographic distribution of resistance?
- What level of resistance, complete or partial?
- What type of resistance – Major gene resistance (MGR) or Quantitative (QR)?
- 0% to 100% survival spectrum – what is adequate for purpose?
- Is it durable? Is it stable? Are there fitness costs?
- How to efficiently setup a resistance screening progam.

Phase 2 Considerations – developing resistant populations

- Is breeding needed or can seed from resistant parent trees be used for restoration?
- Are seed orchards needed? How to protect resistant parent trees?
- What is the expected survival % – how many to plant?

- Who or what group oversees resistant seed development?
- How to organise a successful applied program
- Focus on developing resistant populations, not research
- Large scale screening – must be reliable and correlate with field results
- Infrastructure and personnel needs
- When will resistant seed be available?
- How to maximise restoration?
- How can genomics or biotechnology aid conventional resistance breeding?

Plan forward

- Characterise the problem for all stakeholder communities; keep them updated
- Prioritise actions.
- Define goals under current conditions and through to 'worst case' scenario
- Will response be centralised? If decentralised, how maintain focus?
- What tangible actions can be taken? Interim and advanced.
- How can others help? Expand the network.
- Publicise success stories

Starting a new program – some issues to consider

- Seedling screening and/or accelerated field screening?
- Not all screening assays provide the correct resistance rating!
- What resistance phenotypes are apparent?
- What parent trees to select?
- How large a genetic base is desired?
- Are there different seed zones, and need for separate selections processes in each?
- Are there progeny tests in the field in rust affected areas (high rust areas) – if so, what is the summary information from these areas?
- What level and frequency of resistance is needed?
- How much focus on 'research' versus 'applied breeding'?

DISCUSSION: Practical workflow for resistance breeding

Species selection considerations

- It is important to separate the germplasm conservation collection from the plant screening and breeding process, to retain flexibility in each activity.
- Optimal species for selection trials should display some resistance and some susceptibility.
- Ideally it would be beneficial to select species that are biologically attractive to the public, are easy to collect or store, can help you secure proof of concept, or that offer multiple biological options for breeding (e.g. easily germinable seed as well as vegetative options)
- Incorporating species with economic values (Mānuka as an example) can help attract funding.
- Consider prioritisation of species with cultural values, and co-design of approach for these with First Nations.
- Considering the ecological values of the species can assist with future reintroductions once plant breeding has established resistant species.
- Scoping a resistance breeding program by NZ MPI: two references, both slightly dated but useful, supplied by Heidi Dungey:
  - https://www.myrtlerust.org.nz/assets/Uploads/Scoping-a-resistance-breeding-programme-Strategy-pathways-for-implementa..-.pdf
  - https://www.myrtlerust.org.nz/science-and-research/mpi-research-reports/seed-banking-and-breeding/

Understanding resistance

- There can be multiple avenues for resistance or infection, so it is imperative this is better understood. However, this does not need to be exhaustively studied prior to starting a screening and breeding program.
- Understanding population genetics is important.
- Understanding single species vs multi-species responses is critical.
- Need to distinguish and determine types of resistance/susceptibility: constitutive or induced, qualitative (major gene) or quantitative (multi-locus); also desirable to know what resistance traits are phylogenetically embedded.
- Many variables need to be considered and standardised where possible and necessary: e.g. changes in gene expression (related to factors like plant age, tissue age, climate, season); inoculum concentration; and other.
- Try and incorporate as many phenotypes as possible, if not all available phenotypes.

Understanding reproductive biology

- It is important to determine how much needs to be known about the species before embarking on a program; parallel studies may or may not be necessary.
- Some species have very low seed set and this may limit possibilities.
- Light requirements for some species are not well understood in relation to impact on flowering and fruiting.
- Kinship and breeding can have an impact in field trials that often aren't observed in the nursery – population genetics, life history etc; multiple factors to consider when moving from the nursery to the field.
- Need to be mindful of having too many seedlings from an individual plant, so pollination control can be critical.
- Need to consider translocations carefully, e.g. planting species in areas that may not provide all of the desired/required conditions can compromise the trials. Things to consider may include whether cold stratification occurs, whether flooding or droughts are likely to impact the area, are there niche [availability] issues, will the location encourage inbreeding etc.
- Conversations with First Nations Peoples are essential – elements to consider include, but are not limited to, what and how species can be collected, whether they can be moved around or moved off country, what other cultural relevance may there be that should be considered. What do they want out of process? What is right way? Need for Access and Benefit Sharing arrangements.
- What reproductive requirements do the selected species have? Consider what pollinators may be important – specialist or generalists? What seed dispersal mechanisms do they employ? What is the provenance of the material planted and what may be missing from the trial site that exists in its original habitat?

Determining scale of work

- Species dependant, but may not need a large area; see Lemon Myrtle case.

Designing breeding program

- A recent NZ paper has identified that climate overlap, cultural considerations and ecological importance can assist with the triage of species during the selection process.
- Jules Freeman suggested two useful references: Thumma *et al*. 2013, Molecular tagging of rust resistance genes in eucalypts (Report to Plant Health Australia) [no web version yet found – ROM]; and Yong *et al*. (2021) Genome-wide association study of myrtle rust (*Austropuccinia psidii*) resistance in *Eucalyptus obliqua* (subgenus *Eucalyptus*), https://doi.org/10.1007/s11295-021-01511-0

- Proof of concept can often work well with flagship species. We will need to carefully consider species biology, cultural relevance, economic value, ecosystem services role and other characteristics or values that may be important at landscape or ecosystem level.
- The way the trial works will likely be different based on the species and location selected. Remain mindful of unique elements when prioritising species and developing the program.
- First Nations – There was a noticeable lack of First Nations representation in the room or online. These gaps will need to be rectified prior to developing a program or applying for funding. The inclusion of First Nations Peoples from the beginning is critical.
- Some trials are already seeing differences in the resistance shown in nurseries versus in situ plantings. It is critical that the reasons for these differences are identified in order to validate the trial outcomes in the field.
- Participants were asked to consider whether they would be willing to be in a working group to develop this further. General consensus was that participants would be supportive.
- Should we be putting together a proposal for a scoping study?
- There was consensus that the development of a scoping study should not hold up work continuing where other elements in this space could be progressed.
  - A prioritisation of species would be of benefit; probably prior to a scoping study.
  - First Nations as key participants during species prioritisation and in scoping study.
  - It was agreed that frameworks could be prepared that provided scalable actions. This would position the group to be ready to respond with viable options if money becomes available at short notice.
  - Maori would likely be supportive of elevating germplasm capture and conservation in any scoping exercise. Equally important to this is the need for the Government's response to recognise the importance of codesign and support it to happen.
  - The scoping study must be developed by those with existing expertise, not a consultant with no prior expertise or knowledge of the subject matter.

DISCUSSION: Case study – *Rhodamnia rubescens*

Update on current knowledge of species biology and ecology

The Australian Botanic Garden (ABG), Mount Annan:

- Holds approx. 35 lineages under cover; some replicates are planted out.
- Multiplication using existing germplasm collections; 75,000 seeds collected from 44 plants, noting that some may have been collected from the same plant over two years. Parentage not yet analysed?
- Winter propagation is proving to be the best approach; cuttings strike in 4-6 weeks.
- Some cuttings fail, but cuttings are still the best option for this species if good material taken at right season; however the species does appear to sucker reasonably reliably.
- Three years' maintenance and repropagation experience now gained.
- Plant hygiene a key focus; frequent need for fungicide in recent times due to conditions conducive to high ambient MR spore load. Multiple mitigation measures employed to limit need for spraying, e.g.: no overhead irrigation, holding plants in nursery to limit exposure.
- *R. rubescens* is fast growing if plants have what they need in propagation. This presents its own problems for space and the resources required for managing potted collections.
- Flowering can happen at unexpected times, presenting challenges and potential need for interventions. Can flower in nursery conditions when pollinators were either not present or not able to access (under cover). However, this means that controlled crosses are possible.

Booderee Botanic Gardens (BBG) at Jervis Bay ACT:

- Holds plants sourced from several southern populations of *R. rubescens*.

Queensland (DAF Gympie) holdings are still under development.

Genetics and preliminary screening

Royal Botanic Garden (RBG), Sydney has undertaken work on genetics for *R. rubescens*:

- Tissue samples from across its range, including all lineages held in ABG and BBG collections, have confirmed representativeness of collections made across the range in NSW (Qld samples to be incorporated to inform sampling there). The genetics results have broadly validated the sampling zones defined before the genetic information was available, made on the basis of biogeographic factors, topography, and herbarium and survey record clusters.
- Genetics shows that natural outcrossing; species is probably a preferential outcrosser.
- Conservation genetics will need to be carefully considered.

- Preliminary MR susceptibility assays have been conducted on some ‘spare’ collections from ANBG Canberra and BBG; 7 of 25 did not become infected.
- Tested 21 maternal lines from ABG Mount Annan collection of seedlings. Of 250 plants assayed, 127 did not become infected, noting some fertilisation bias. The 127 seedlings that were found to be resistant are still in the nursery at ABGMA. Recommendation that some of these be planted for testing in the field or living collection at ABGMA.

Reproductive ecology

- *R. rubescens* appears to only require generalist pollinators, nothing unique has been recorded in the field. Work to determine associated invertebrates would be of value.

Considerations for further work

- It would be beneficial to long-term ex situ conservation to identify alternative/additional regional locations as for holding collections.
- Genetic profiles are needed or desirable for all target species.
- Frost is a key threat to planted-out collections at ABGMA, so covered nursery and maintenance house facilities are key to maintaining collections in the short term. Future work must consider these elements in any field trials, in situ restoration, translocation plantings, and displays.
- There still exists some resistance to spraying plants, both at the institution and individual employee/volunteer level; this is known to apply at various prospective future partner gardens also. Must respectfully engage in this space to identify options and find resolution.

How would the outcomes/considerations of the morning ‘workflow’ session apply to a resistance breeding program of *Rhodamnia rubescens*?

- Should focus on listed species [not all agree on this – ROM] and capitalise on already established cultural connections. Need to better promote progress made to date.
- Should not lose focus on potential new incursions from other rust biotypes. International collaborations key to making progress and avoiding duplication of effort and investment.
- Different facilities use slightly different methods for inoculation and screening, e.g. spore concentrations and application methods, leaf age, leaf condition etc. Researchers need to be aware of these differences so documenting and sharing these methods should be prioritised if not available in the published literature.
- Where possible, establish standardised methodologies.
- Baseline genetic markers are highly valuable. Can compare with reference genome where known, but this can be tricky when working with small sample sizes.

- Risk management for ex situ collections is important – managing collections is labour intensive, there are risks of loss, especially when considering the challenge of how we secure these long-term due to space and resourcing limitations in both smaller and larger nurseries, botanic gardens etc. Dispersal of metacollections is an important option in managing this risk (seed banks, botanic gardens nurseries, arboreta etc).
- Trials were undertaken for storage of *R. rubescens* at various temperatures by Karen Sommerville at PlantBank; see Sommerville *et al*. (2019), https://doi.org/10.1071/PC19026
- Genetic studies need to ensure scale is carefully considered – 400-500 plants in a trial is the lower limit to do the genetic study properly. The larger the trial the better.
- When selecting eventual translocation sites, we should be prioritising assessments of the ecological community. This has already been done for some locations. Issues to consider include pollinators, species reliant on the target species for habitat or sustenance, and in some areas, other plant colonisers that may serve to reduce the available habitat for the translocations.
- Field trials can require up to 4-8 people depending on the size, competition, density of the bush, what measurements are to be collected, etc. In NZ, Scion sites may have regular weed control actions but are not revisited for data collection for up to 8 years. However, each species will be different, visits may occur sooner or more regularly.
- Co-planting should be considered, e.g. if shading is needed to provide more suitable growing conditions or protection.
- The fragmentation of populations could be used as a justification for bringing individuals from fragmented populations together to test whether resistance traits already exist, and can be easily identified prior to selecting individuals for translocation programs.
- Collection size – we need statistical power in the genomics. This is complicated to achieve but not having this should not delay commencement of other work.
- Do what you can with the resources and collection size you have, building in the elements we know we need to consider, such as cultural considerations, locations of trials etc.
- Keep devolved tasks simple!
- Genome-Wide Association Studies (GWAS) are part of the toolkit; see, e.g., Yong *et al*. (2021), https://doi.org/10.1007/s11295-021-01511-0.
- First Nations collaboration projects are already happening in some places: with Iwi in NZ and First Nations Australians K'gari Qld and NSW North Coast.
- Two-way collaboration with First Nations – We need to be sharing more with each other about the various approaches to how it is done well. It is imperative that we are listening, learning and delivering trials according to how First Nations want to see it done on country. We may not quite get the genetics we're after using this approach, but the other outcomes can be much more rewarding. Screening here could focus on natural selection.

- Need to consider that it may be quicker to do field trials rather than nursery trials in some cases.
- Trial screening of *R. rubescens* at ABGMA initially occurred on seedlings a couple of months old, cuttings were established over a period of 12 months.
- At what age are we screening these individuals? 1 year, 2 year, older? And when do you apply fungicides relative to screening process? ABG Mount Annan comment: material reared for screening was never taken out of the sealed glasshouse facility; preferred approach was to have six week break between fungicide spray and screening.
- Best to avoid fungicide if you can avoid it, particularly long-term systemic ones. Six months may be the necessary break in these instances to avoid confounding results.
- When developing proposals to support this work we should include specifications and options for both larger and smaller array screening and breeding in both local and more away-from-country central situations.
- Need close communications and skills exchange networks that support broader collaboration and break down silos of expertise.
- Need good nursery propagation methods and dedicated / resourced people. Resourcing and training for these elements must be consistent and reliable. No good having things germinating if we can't propagate and maintain them.
- Space and capabilities are limiting factors, so is conservation horticulture skill. The sector needs to ensure there is training available. Potential for this to be delivered by the Australian Network for Plant Conservation (ANPC)?
- Even larger organisations like ABGMA don't have capacity to deliver these programs at scale. ABGMA can certainly work across networks and help with training, but the effort needs coordination that is adequately funded. Continuity of staff to be able to follow projects through from inception to completion are critical. As well as staff to maintain collections in living collections when projects formally finish.
- Need proper facilities, people, training, etc. A dedicated capability, sometimes including sub-facilities, is important for any metacollection custodial partner.
- Options for metacollections/field trial tenures include botanic gardens, conservation nurseries, some university and TAFE campuses (e.g. Coffs Harbour), and some agricultural field stations.
- AGREED that *R. rubescens* is a good starting subject for a trial screening and breeding program. Other species are also possible.

Workshop time did not permit discussion of a second case study (*Melaleuca quinquenervia*), but this is a viable trial species and is already the subject of some preliminary work (see Bragg and Martino presentations at AMRC2023).

What expertise do we need? Where do we find it?

Plant pathology

Primary Industries agencies; some universities; one or two botanic gardens; some industry bodies?

First Nations

- Critical to do this properly from the outset. First Nations Peoples must be provided the opportunity for full participation in program design and implementation for trials to be effective over the longer-term.
- An extended comment was posted in the online Chat during this session from Melanie Mark-Shadbolt, who is Independent Chair of Better Border Biosecurity (B3), NZ, and Co-Founder & Trustee of the NGO Te Tira Whakamātaki (https://ttw.nz/):

  "So a quick look at all those guidelines [uncertain which – ROM] – they refer to Aboriginal ethics in other documents but give no real consideration for Indigenous rights, expectations and or ways of operating/knowing/interacting with each other. So I still can't figure out how Aboriginal or Māori peoples are central to this conversation especially since in NZ Article 2 of the Treaty guarantees us Rangatiratanga (sovereignty and control) of all taonga species and lands. That means nothing can be done without our involvement or arguably our leadership - we have sovereignty over taonga confirmed in various Settlement Act's also. This is more than just 'consultation' or 'knowing a Māori', as is clearly outlined in NZ's Public Service Act.

  "I'm sure there are similar guarantees in Australia and suggest you all review Terri Janke's work on IP if you want direction [see, e.g., publications at https://www.terrijanke.com.au/resources]. Terri's team are working with us to write seed protocols for NZ and will no doubt repurpose them in Oz with their communities.

  "I'm really nervous that what I am hearing is a pitch for money (which I support), with Indigenous people as an after thought or 'selling point' (which I don't support). Many of you sound like you are working with an Indigenous communities, but you don't represent them or understand their needs fully. They/we need to be at this table, and at their/our own table having this korero/conversation. I hope step two is to bring them into a conversation ... happy to have a conversation and share what we are doing in this space."

Silvicultural and specialist horticultural and horticultural science

- Horticultural and horticultural science skills are critical for managing collections in the nursery – the specific expertise these roles bring are paramount to success.
- Conservation Horticulture is a growing area of focus that will provide important contributions to any program. Includes a suite of related activities - collection, propagation, maintenance of potted or display collections.
- Australia is currently at capacity in relation to the number of staff available to support these programs, at least in public institutions – note the many competing priorities in the threatened species space. There are problems in expanding capacity due mainly to tight budgets, staffing caps imposed by governments, and predominantly short-term project funding that impacts ability to maintain currency and capacity of staff. Relying on short-term staffing to support these programs is not a viable option as it opens the program to greater risk of inconsistent care of material and loss of knowledge and skills as staff move on at the end of projects, despite material remaining in collections. We need qualitative breakthroughs on these issues.
- Suggested that organisations like Tree Breeders Australia could be contracted to assist trials.
- Horticulture and forestry tree breeding can be very similar; many transferrable skills that available if we can successfully engage forest breeders in our programs.
- Our linkages with commercial breeders are not yet well established enough for their deep involvement as co-applicants in grants. This area needs some specific focus to develop the relationships, establish shared goals or interests, and prepare them for inclusion in future resource bids.

Entomologists

- Research is underway in some areas to identify linkages between pollination vectors and impacts.
- Brandan Espe identified several areas where work is already underway in North Queensland looking at flora/fauna associations – including avian, insect and mammal associations.

Skills assembly and training

- Trials will rely heavily on multidisciplinary teams that include field technicians, data analysts, 'omics' geneticists, propagation horticulturist, coordinator, communications specialist, forest ecologist (including microbiology), First Nations representatives.
- Skills development across the sector is a priority – We must work with First Nations Peoples and regional botanic gardens and nurseries to help them develop relevant skills to enable participation in the program.

- Capacity building within and across the community, particularly regarding cultural protocols that we can learn will be key to success. On-country visits are a must for establishing trust and relationships.
- Exchange of staff between institutions such as botanic gardens will enable staff to learn or refine skills and expertise not yet fully developed in smaller organisations. BGANZ is supporting gardens in this space already for general horticultural skills, and is undertaking an evaluation of what's possible and important for them to support in the years ahead.
- We need to work smarter – for example we should look to use local contacts for expediting the granting of collecting permits, or for sharing collections under an existing permit, or to assist with establishing relationships with local communities to be able to collect on Country.
- We need to take the opportunity to share what we know through less formal seminars. Grey literature sources will also be important for sharing knowledge otherwise not widely available. Facilitating online chats or webinar series will continue to be valuable forums for sharing knowledge and seeking guidance from peers. Regular meetings key for sharing information. BGANZ meetings are currently held every 2nd month providing a regular (but not too regular) forum to catch up, share and learn.

Communications and knowledge management

- The group was asked whether there would be support for developing an online resource that aggregates the information that is already available – this could take the form of a manual of best practice. In-principle agreement, although this cannot be done in-kind and must be resourced.
- The ANPC's *Australasian Plant Conservation* quarterly bulletin brings together significant information on plant conservation. Could consider recommending ANPC include a sub-element of this to focus on Myrtle Rust.
- NZ does have an information repository established and available online, but it is in a bit of a holding pattern due to lack of funding. Can be reinvigorated once funding is available.
- There was recognition that in both countries, resourced coordination is needed longer term for information hubs to be successful ongoing, reliable resources.
- How do we establish standards for everyone to adhere to? An options paper could be developed for this by SCION reps.

Additional items earmarked for this session, but not discussed in detail for lack of time, were:

Genetics; Plant biology and ecology: '**Omics' techniques; Permissions and social/cultural licence; Ongoing stakeholder liaison**; **Coordination; Promotion and Championing (political, bureaucratic, media …)**; **Specialist fundraising.**

What facilities do we need? Where do we find them?

Physical assets – built facilities and land

- When selecting facilities or locations, they must be considered within the context of a robust risk analysis matrix and risk management framework. The Operational Plan for ANPC's 'Safe custody of *Rhodomytrus psidioides*' project of 2021–3 has a strong risk checklist (pp 12, 13, and Appendix 1), available on request.
- There was agreement that we would benefit from an audit that identifies which organisations have what facilities at their disposal, and access conditions. Also worth capturing is which of these are already at capacity and which have capacity to assist any future program. Results could be made available via a directory of sorts. Botanic Gardens Conservation International Garden Search tool could be a model to replicated.
- Larger botanic gardens are often better equipped to accommodate visiting staff and to provide capacity building support. Note that the BGANZ Botanic Gardens Conservation and Records Management (BCARM) group is currently led by Sheree Parker at Kings Park in Western Australia – best contact for discussing the work on staff exchange opportunities being facilitated by BGANZ.

General considerations

- Need to consider whether we will establish trials in areas that are considered within or outside of the expected zone of occurrence of Myrtle Rust.
- Public and neighbour perceptions.
- Proximity to needed expertise and oversight.
- Need s string risk/mitigation analysis – see NSW operational plan for Native Guava project for example.

Conservation sites for core wild lineages (includes propagation areas, shade houses, disease management)

- Not necessarily the same sites as are used for screening, breeding, outdoor exposure trials, or seed production. May be better not the same – analyse pros and cons.
- Selecting a location will take time – sites need to be identified, evaluated and if appropriate, secured. Communities, First Nations Peoples, Researchers etc all need to trust the intentions, the process, and the intended outcomes.
- Any program needs to determine whether it will incorporate single-species or multi-species plots. This can be particularly important to consider as mixed plantings could lead to plants in the trials being at risk of compromise due to competition in the planting, increased spore load due to other species susceptibility, hybridisation, etc.

Sites and facilities for resistance screening

- Quarantine facilities will be important resources at some locations, particularly if introduction of myrtle rust is a risk when moving material inter-site as part of trials or metacollection management.
- In NZ, in situ field trials can sometimes be preferable when a trial simply needs to commence. In these instances, you will be relying on local inoculants rather than a controlled inoculation.

Sites for breeding and resistance trials

- Ideally, we want to minimise the risk of spore load to ex situ collections where trials are being conducted, particularly when testing wild lineages. Ideally trials would be best if they are not run near known sites of rust outbreaks. Custodial sites for wild lineages should not be subject to high spore load, if alternative sites with suitable climate and low risk etc are available. Alternatively, we may sometimes want to identify situations where sending material to areas with high spore load is needed so that we can adequately test for resistance under real ambient conditions. These considerations will inform how and where we are willing and able to send material for ex situ collections and in situ conservation plantings.
- Consider ambient local spore-load and its variation, and sources. In Queensland, the hot spots for disease that have been identified tend to coincide where tourism is a key activity in the area. NZ site disturbance in hot spots is a growing factor of concern; light, space and rainfall considerations are all important for managing new growth and suppressing spore load.
- Site location for in-ground field trials is still a space where more work is needed so that we can secure commitment from adequate facilities – site selection may be key to success.
- Some conditions will mean management scenarios will be more or less burdensome or resource-dependent – for instance, the need (or not) for dedicated irrigation of planted-out will be very much site dependent.
- Substantial preparation is required where we are looking to conduct trials on-country. Discussions and negotiations will take time and effort. If approvals possible, can First Nations Peoples be closely involved in trials, particularly where plants require a higher level of monitoring and care during the trial phase?
- Trials should be optimised for the pathogen, particularly to ensure the facility is managed to prevent pathogen escape (if ambient spore loads are low or zero). Also important to analyse risk of outward transmission by humans (hats, clothing, etc), including to areas with no current Myrtle Rust presence. Public sites particularly problematic in this regard.
- Need to demonstrate our ability to deliver any such program with both larger centralised arrays and smaller local arrays. Doing so may help with proving to communities and First Nations Peoples that we are committed to delivering this the right way, not just in city centres with no regional or First Nations input.

- Concerns were raised about how we deliver consistent design approach and scoring, which brought discussions back to developing shared methodologies or standardised approaches.
- It will be important to incorporate multiple trial sites to deal with climatic gradients. Learning from the North American experience – considerations include site accessibility and ease of maintenance, local spore load. As the number of sites increases, it is possible to become more selective about the sites from a resource, effort and suitability basis.
- Smaller arrays versus larger arrays will likely be site dependent and need to be carefully considered.
- Biosecurity is one of the key barriers to moving material around so some trials will not be possible across all landscapes. Need to consider whether you are compromising local in situ resistance by introducing individuals with different resistance profiles e.g., higher-resistance individuals may encourage the rust to evolve and increase risk to in situ populations that demonstrate less resistance.
- Field trials should also include consideration for whether incorporating exotic species is a viable option.
- Trial sites may need to consider whether they are viable based on their proximity to where in situ populations already exist.
- Important to evaluate what level of servicing these local trial sites are likely to need, e.g., frequency, duration, number of staff for each visit.

Tenures and general tenure considerations

- In NZ, consideration and respect for the Iwi is paramount – considerations need to be given to where material is coming from and where it is going to – respect is key in negotiating these circumstances.
- In Australia – co-design discussions with First Nations about on-country options could include whether Indigenous Protected Areas (IPAs) might be potential sites for field trials of local-origin candidate resistant plants. Given that most IPAs are remotely located, they will be heavily reliant on building capacity on-Country and providing support for longer term monitoring and management. IPAs are reliant on grant/government funding so these additional activities cannot be absorbed into business as usual practices. Capacity building and training in land management, propagation and maintenance of collections and plantings may be welcome, but co-design is key.
- Need to consider what other stakeholders' priorities may be, and be willing to make space and time to build these into the program design, e.g. nurseries that can also accommodate collections for local community use.

- Local Councils should not be neglected as potential partners for some aspects of MR species recovery actions. Plantings in council landscaped and amenity areas, and on Council reserves, may be feasible in some circumstances. Again, full analysis of risks, mitigation, and mutual capability is needed in each case. Examples cited in discussion: Townsville Council (Qld) was provided material from James Cook University, with JCU managing the data for the plantings; in NZ there are similar landscape plantings with data managed by Auckland City Council; in NSW the Council-run Lismore Rainforest Botanic Garden is a custodial partner in the Native Guava project. Noted that some/many councils already have local council street tree health monitoring in place – discussions with Council Environmental Officer networks might open up possibilities.

How do we pull all of this together into a document for convincing funders etc that this complex approach is critical to success?

- Coordination/Coordinator – The existing network is important for ensuring information flow and knowledge sharing. Other supporting activities such as shared resourcing, capacity building and coordination can all be brought to bear where it is most needed at the right time given the strength of the network.
- The previously mentioned audit/inventory of existing facilities was raised again as a critical element to undertake – TAFE, IPAs, nurseries, botanic gardens, private facilities, State Government research facilities, University facilities etc. Consider proximity of local expertise, local capacities, and First Nations communities when determining whether a facility is potentially suitable.
- We need to consider how we prioritise species that will enable us to show evidence of success. This will underpin future requests for support to scale up to dozens of species in similar trials. It is imperative that we develop a generic plan for one species that can be scaled up for multiple species at any given moment.

Site disaster risks, mitigation options

- New South Wales participants noted that that State has legislative provision to declare *Assets of Intergenerational Significance*, resources and assets to be protected due to environmental and/or cultural significance. Fire management planning processes used in NSW National Parks have to take account of these. It is yet to be determined whether this approach can extend to areas outside of NSW National Parks. Noted that as of 1 July 2023, Botanic Gardens of Sydney sits within DPE Crown Lands, so may be eligible as a case for the definition to apply to more Crown Land sites.

Funding

- It is important to chase both short- and long-term funding, and maintain a game plan that is adaptable based on scale of available resources.
- The first five years can be very important to build momentum and justify the approach taken. Once proof of concept is established, 20-year plans can be presented to funders. At current stage it is important to have multiple options in planning so that as a network we can respond to emerging opportunities be they risk-based or funding-based.
- *Catalyst* program funding from NZ could work for a start-up program in that country. The NZ Ministry of Business Innovation and Employment administers *Catalyst*, providing a three-year funding program with potential for future proposals if a continuing program is supported by Government. All proposals must meet the criterion (among others) of being a new relationship/ issue to receive funding. Current *Catalyst* project collaborations have included Qld DPE, NSW DPIE, and ANU. *Catalyst* also has relationship-building funding – one of the four streams – including strategic funds for research and travel.
- It was recognised that given the biology of the pathogen, we essentially can't directly stop the Myrtle Rust threatening process, so funding needs to go to a more roundabout conservation effort instead. This is a key consideration to ensure limited funding is appropriately targeted.
- Mention was made of a recent (April/May 2023) call for species rescue concept proposals from the Australian Government. A Myrtle Rust EOI was submitted through the ANPC, outlining at a concept level three interlinked Myrtle Rust areas needing funding, and which already have a strong level of foundational work and established collaborations. These were: Indigenous engagement on biosecurity and forest management; germplasm capture and resistance breeding in south-east Australia; and a similar program in north eastern Queensland. If the EOI group is invited to proceed to a full proposal, an expanded scope and partnership list could be considered.
- Auckland City Council is developing a program and funding for how priority species are managed across the board, in situ and ex situ.
- Funding from non-orthodox places such as the Great Barrier Reef Marine Park Authority (GBRMPA) for Qld species could be worth exploring further, since they work on coastal matters that impact water quality on the Reef. Loss of ecosystems can result in greater sediment load to the Reef in key locations. Particularly *Melaleuca*-dominated swamps that are relied on for water filtration.
- NZ and Australia can both use examples from each other to demonstrate to local funders that they should increase their support for work in-country and across borders.
- NZ is currently going through a change in its science system so there will likely be changes to the way support can be accessed and new opportunities that materialise. See Te Ara Paerangi Future Pathways, https://www.mbie.govt.nz/science-and-technology/science-and-innovation/agencies-policies-and-budget-initiatives/te-ara-paerangi-future-pathways/ for developments to date.

- There are examples from the Australian alpine region where Australian Research Council (ARC) Linkage grants have supported industry and university partners to develop facilities and equipment, rather than funding straight research. This stream could be accessed for development of facilities where they are most needed but that are unlikely to get funding from elsewhere.
- Ian Potter Foundation (IPF) – innovative projects are likely to be of interest. Myrtle Rust has been proposed before, but not yet funded. It has become evident that IPF is very interested in Very Big Ideas. Scaling up from business as usual is likely to be more palatable e.g. proposing a program of work at a national scale rather than a discrete project.
- It was noted that while there are some contacts within the wider Australasia / Oceania and south-east Asian regions (i.e. outside Australia and NZ), many more are needed to establish meaningful conversations across the region. In Australia, the Department of Foreign Affairs and Trade (DFAT) may be an option for funding, although we would need to establish support and the 'need' in-country first so that local program partners can advocate to the relevant Australian High Commission, while Australian-based program partners lobby DFAT in Canberra. Note also SPREP (Secretariat for the Pacific Regional Environment Program – https:// https://www.sprep.org/), and the Māori biosecurity network Te Tira Whakamataki (https://www.ttw.nz/).
- Note also potential use of Churchill Fellowships, Fulbright Scholarships (US), The Crawford Fund (Australia). Also Eucalypt Australia (Dahl Trust, but this is $25,000 a year so small focus only).
- Given the above, we should consider whether we can strategically combine smaller efforts so that they can be incorporated into a larger program of greater benefit.
- In New South Wales, the NSW Environmental Trust funds some medium term (5–10 year) projects of strategic environmental value – conversations should be had with them.
- Franklinia Foundation – https://fondationfranklinia.org/en/soumettre-un-projet/ - Swiss organisation.
- Also to evaluate for potential assistance: Botanic Gardens Conservation International (BGCI: https:// https://www.bgci.org/), and the Global Conservation Consortia (https:// https://www.globalconservationconsortia.org/); these have previously helped with Kauri conservation in NZ.
- Queensland's Nature Assist Program – landowners can sell land to get credits. https://www.qld.gov.au/environment/parks/protected-areas/private/natureassist
- NZ Endangered Species Foundation: https://savethehighseas.org/about-us/members/endangered-species-foundation/
- A full inventory of likely potential support bodies is clearly needed.

Addressing gaps in infrastructure

- It was noted that in NSW, Botanic Gardens of Sydney has just completed a new business case for nursery facilities; it was suggested that this workshop group could usefully inform BGS what may be needed to fill critical infrastructure gaps. The ABG Mount Annan nursery in south-western Sydney is the crux facility of BGS (along with the associated PlantBank germplasm collections and research).
- For Australia, it was noted that we need to be part of the conversation with the Commonwealth in the run-up to their revision of the *Threatened Species Strategy* (due 2025–6).
- Duplication of collections is important for their security. An example was provided where myrtle rust spores held in University of Sydney cryo collections are not yet duplicated at another site.
- In NZ, the Scion Research nursery was recently upgraded, and they are open to sharing learnings from that process.
- Some 'must haves' for nursery facilities include fogging chambers, flexible heated benches, and large shadehouse maintenance spaces.
- First Nations cultural connections was again raised as a key gap.
- In the US, this year's Federal budget increased significantly for urban forestry. It would be beneficial to understand what the driver was for this (climate change adaptation in part, but other elements?)
- We need to consider who else we need to assist us sell this message - social scientists, economists, or others to provide a different perspective and assist with firming up the argument.
- Carbon capture – may need to establish justification for future plantings. Baseline data of existing stands does not yet exist for many species, so may be hard to establish, although Stevenson's (UQ) work shows some calculations are sometimes possible.
- Myrtle Rust community needs to do better at engaging with TERN (Australia's Terrestrial Ecosystem Research Network), and utilising their monitoring stations where relevant.

Additional items earmarked for this session, but not discussed in detail for lack of time, were:

- **Other potential tenures: Ag department sites**; **botanic gardens (metro and regional)**; **universities**; **private arboreta and lands.**
- **Fitting diverse tenures into program architecture**: **standardisation of approaches, training, quality assurance.**
- **Consumables.**

Species priorities and constraints

Assessing threats and impacts to enable prioritisation of conservation actions

- Legislative listings usually have a quantum of expert knowledge and often data behind them, but this may become outdated very rapidly. Myrtle Rust is a very dynamic threat; keeping threat assessments up to date for it is not straightforward, and definitely requires resources including for field assessments and time-series monitoring. The consequences of not actively updating threat/decline assessments can be serious loss of diversity and an inhibited conservation response.
- Legislative listing systems in Australia vary with jurisdiction, but few allow for precautionary listing, and most are now (under the Common Assessment Methodology) quite data-hungry before new listings or changes in categorisation can be enacted. Australian listing systems have lagged a long way behind demonstrated impacts from Myrtle Rust. The tendency for conservation action funding for species to be tied to listing status, has been a counter-productive factor.
- Aotearoa New Zealand listed many Myrtaceae as Threatened after Myrtle Rust arrival. Hard data on declines and impacts is still lacking for many, but is now starting to be demonstrated for some (e.g. *Lophomyrtus bullata* Ramarama; *Syzygium maire*, maire tawake).
- In neither country is there yet much progress in establishing long- or even medium-term term monitoring; most quantitative assessments have been based on one or very few site visits; most general surveys have been snapshots. These yield valuable observations, but do not provide the definitive information that may be needed for legislative list adjustment,
- In NZ, there is limited administrative focus on species in the wild so far, and a lack of knowledge of impacts across species due to limited monitoring across the board. *Metrosideros* species are known to have been impacted in some monitored areas, but the overall challenge of limited monitoring still exists.
- For Western Australian species, and for those found on Lord Howe Island, there is currently a (probably limited) opportunity outside of an emergency response, to consider the elements that might or should contribute to prioritisation of species, whether for pre-arrival precautionary actions, or contingency planning for actions during and after an incursion. These may include taxonomic considerations (including phylogenetic distinctiveness), and rarity or unique attributes of species.
- New Zealand did not always have sufficient cultural overlay when starting their Myrtle Rust response. However, this is changing and is now coming first which is how it should be.

- In North Queensland, some work is being done to determine which species are significant for traditional and contemporary cultural uses (bush tucker, tools, medicines), or may be used in other cultural artefacts and practices. This includes First Nations Peoples bringing their perspective to identifying species with known habitat and ecosystem function, that if lost, would result in environmental deterioration. Multiple NQ species are considered Data Deficient for legislative listing purposes. Listed species in some areas are assumed to not have rust, but more monitoring is needed to test this assumption and evaluate any impacts.
- Need to consider what role a species has in regards to ecological function for the landscape e.g., food plants, fungal associations, habitat etc.
- Participants from both countries reiterated that it is critical that more information is gained to identify faunal, flora, and fungal dependencies on myrtle rust-affected species.
- Members of the network are continuing to make the argument for why 'low priority' species are important and worthy of the limited available funding to ensure they are not lost in the process.
- Funding is needed to support further research that can determine what species can be stored, and how.
- In New Zealand, Pōhutukawa (*Metrosideros excelsa*) may be the species most likely to attract funding given its iconic and cultural status; it has already attracted some funding for research, but less successful for operational funding. Mānuka (*Leptopsermum*) and kānuka (*Kunzea*) have potential to attract funding from commercial entities, not just governments.
- No plant family in Australia has ever had a full published evaluation of their 'total values', economic, ecological, and other. Australia is missing the vernacular to compete with the NZ approach to valuing and communicating the cultural/ecological (etc) importance of plants – 'taonga'.
- Species with a commercial interest can be attractors for funding even if not priorities in other respects, so it will be important to find meaningful associations that allow non-commercial species to be incorporated in such studies (i.e. enabling piggy-backing).
- May just need to consider prioritising everything now, as much as we can, given that the limited and disjointed nature of resourcing and lack of baseline makes a mess of rational prioritising, which in any case requires significant investment and continuity of effort. External players insisting on strict prioritisation approaches, in the absence of much needed data, may be doing more harm than good.
- Synergistic effects need to be considered – We must not lose sight of those species previously identified as common that may now be threatened, including any similar examples that could be inferred to have a similar response in the future
- Do we need to do a risk assessment/audit of where we're at right now? Could be incorporated into the facility audit.

Closing comments (informal) from Richard Sniezko

- The Australian and NZ situation makes the American challenge look simple.
- There will never be enough funding.
- Priority lists are key, ensuring we include relevant, biological information to justify to funders – need to think about those previously discussed data gaps.
- A multidisciplinary approach (including social, economic, etc) is essential.
- Start somewhere, document your successes, and build from there.

After several intense days, a number of additional items earmarked for this session and relating to prioritisation were not discussed in detail for lack of time. These included:

Program Risk Analysis

Species with observed resistance in the field (known something to work with)

- **Species with no observed resistance exhibited in the field or in early trials**
- **Species we have pre-existing expertise in**
- **Species with amenable biology (e.g. seed orthodoxy etc)**
- **Species of cultural priority**
- **Species amenable to small on-country work including complementary management**
- **Species of linch-pin ecological function**

AMRC2023: Conference program

Wednesday 21 June 2023 – Day 1

Times	Presentation	Speaker
8:30 – 9:00am	Arrival and registration	
9.00 – 9.05am	**Introduction**	Peri Tobias
9:05 – 9:40am	**Welcome to Country and First Nations address**	Metro Local Aboriginal Land Council representative, followed by Māori representative/s
9:40 – 9:50am	**Opening Address** Australian Chief Environmental Biosecurity Officer Department of Agriculture, Fisheries and Forestry	Dr Bertie Hennecke
9:55 – 10:55am	**Update on the status of myrtle rust and response in the Australasian region** Australian perspectives (30 minutes) New Zealand perspectives (30 minutes)	Bob Makinson and Geoff Pegg (Australia); Beccy Ganley and Roanne Sutherland (Aotearoa New Zealand)
10:55 – 11:15am	**Morning tea**	
Morning session	**Fundamental science of the pathogen and host**	**Session Facilitators:** Beccy Ganley and Peri Tobias
11:15 – 11:30am	Perspectives on rust incursions	Robert Park
11:30 – 11:45am	Working towards understanding the host:pathogen interactions	Peri Tobias
11.45 – 12.00pm	Comparative genomics to decipher adaptation of the fungal pathogen *Austropuccinia psidii* to host species in the Myrtaceae family	Thaís Boufleur
12.00 – 12.15pm	Exploring post-transcriptional modifications during myrtle rust pathogen-plant interactions	Ashley Jones
12.15 – 12.30pm	Transcript to protein: understanding the early pathology of the Austropuccinia psidii–mānuka interaction	Rebekah Frampton

Times	Presentation	Speaker
12:30 – 1:30pm	**Lunch**	
Afternoon session one	**Fundamental science of the pathogen and host**	**Session Facilitators:** Alyssa Martino and Stuart Fraser
1:30 – 1:45pm	Solving a perennial problem:double-stranded RNA prevents and cures infection by myrtle rust	Rebecca Degnan
1:45 – 2:00pm	Double-stranded RNA as a sustainable control for myrtle rust	Anne Sawyer
2:15 – 2.30pm	Metabolomics identifies species-specific biomarkers of resistance to *Austropuccinia psidii*	Michelle Moffit
2:30 – 3:30pm	**Afternoon tea**	
Afternoon session two	**Fundamental science of the pathogen and host**	**Session Facilitators:** Grant Smith and Peri Tobias
3:30 – 3:45pm	*Melalueca quinquenervia*; towards a model for myrtle rust research	Alyssa Martino
3:45 – 4:00pm	Building knowledge infrastructure for the conservation of myrtle rust impacted species	Stephanie Chen
4:00 – 4:15pm	Associated fungal diversity of the mid-storey tree *Lophomyrtus bullata*	Mahajabeen Padamsee
4:15 – 4:30pm	Breeding and genomics as a possible pathway for resistance to myrtle rust in New Zealand Myrtaceae	Heidi Dungey
4:30 – 4:45pm	Wrap up and summary	Angus Carnegie
4:45 – 6:45pm	**Poster session, networking, drinks and canapes**	

Thursday 22 June 2023 – Day 2

Times	Presentation	Speaker
9:00 – 10:00am	**Keynote Invited Speaker:** USDA Forest Service, Dorena Genetic Resource Center, Oregon, USA	**Dr Richard Sniezko**
Morning session one	**Indigenous perspectives**	**Session Facilitators:** Maj Padamsee and Bob Makinson
10:00 – 10:15am	Queensland/New South Wales indigenous perspectives	Tilly Davis and AJ Perkins
10:15 – 10:30am	Indigenous responses to taonga impacted on by myrtle rust	Alby Marsh
10:30 – 10:45am	Significance of aka vines (*Metrosideros* spp.) to maaroi	Hone Ropata
10:45 – 11:05am	**Morning tea**	
Morning session two	Biosecurity	**Session Facilitators:** Grant Smith and Maj Padamsee
11:05 – 11:20am	Lessons from Lord Howe Island: An opportunity for eradication	Cristina Venables and Nicola Fuller
11:20 – 11:35am	How to prepare for novel incursions? Using sexy genes to call lineages in the myrtle rust pathogen	Zhenyan Luo and Austin Bird
11:35 – 11:50am	Pre-visual and early detection of myrtle rust on rose apple using hyperspectral measurements and thermal imagery	Michael Bartlett
11:50 – 12:05pm	Using spatial models to identify refugia and guide restoration as part of New Zealand's response to myrtle rust	James McCarthy
12:05 – 12:20pm	Remote sentinel spore sampling	Benjamin Schwessinger
12:20 – 12:30pm	Conference Group Photograph	

Times	Presentation	Speaker
12:30 – 1:30pm	**Lunch**	
Afternoon session one	**Environment and Ecology**	**Session Facilitators:** Stuart Fraser and Angus Carnegie
1:30 – 1:45pm	WA Myrtle Rust Working Group update: A collaborative response to detection in the remote east Kimberley	Mia Townsend
1:45 – 2:00pm	Myrtle rust infection of an endemic rain forest tree across a forest edge gradient in New Zealand	James McCarthy
2:00 – 2:15pm	Impacts of myrtle rust induced tree mortality on nutrient cycling in a wet sclerophyll forest	Kristy Stevenson
2:15 – 2:30pm	A versatile model for assessing climatic risk of myrtle rust	Robert Beresford
2:30 – 2:45pm	Conservation and restoration of species impacted by myrtle rust: translating genetic data to actions	Jason Bragg
2:45 – 3:00pm	Seasonal progression of myrtle rust on *Lophomyrtus* trees in New Zealand leading to declining health and reproductive potential	Michael Bartlett
3:00 – 3:30pm	**Afternoon tea**	
Afternoon session two	Informal Discussions	**Facilitator:** Geoff Pegg
6:30pm	**Conference Dinner at Rydges Sydney Central Hotel**	

Friday 23 June 2023 – Day 3

Times	Presentation	Speaker
8:55 – 9:30am	**Conservation Day – Welcome and Introduction**	Bob Makinson
Morning session one	**Conservation and Applied Science**	**Session Facilitators:** Craig Stehn and Bob Makinson
9:00 – 9:15am	**Session Keynote:** A conservation perspective of managing myrtle rust in Aotearoa New Zealand	Roanne Sutherland
9:15 – 9:30am	A pilot model for development of dispersed collections (metacollections) affected by Myrtle Rust	Amelia Martyn Yenson
9:30 – 9:45am	Conservation programs for two 'emergency' species (*Rhodamnia rubescens and Rhodomyrtus psidioides*) and projected other activity	Craig Stehn
9:45 – 10:00am	Saving Queensland's endangered Myrtaceae from myrtle rust	Fiona Giblin
10:00 – 10:15am	Seed banking options for conservation of species susceptible to myrtle rust	Karen Sommerville
10:15 – 10:30am	Biotechnology offers an alternate conservation pathway for exceptional Myrctaceae species affected by myrtle rust	Lyndle Hardstaff
10:30 – 10:40am	Q&A	Session Facilitators
10:40 – 11:00am	**Morning tea**	
Morning session two	**Conservation and Applied Science**	**Session Facilitators:** Craig Stehn and Bob Makinson
11:00 – 11:15am	Australian Government planning approaches to abating myrtle rust and other key threats to Australia's threatened species and ecological communities	Ben Alter
11:15 – 11:30am	Managing living collections in response to a biosecurity incursion	Emma Simpkins
11:30 – 11:45am	North Queensland impacts and prospects	Darren Crayn
11:45 – 12:00pm	Developing cryopreservation for endangered Gossia – a genus of plants threatened by Myrtle Rust	Jingyin Bao
12:00 – 12:15pm	Fighting Myrtle Rust with ex situ collections data	Bradley Desmond
12:15 – 12:30pm	Q&A	Session Facilitators

Times	Presentation	Speaker
12:30 – 1:30pm	**Lunch**	
Afternoon session	**Workshop: Conservation and Applied Science**	**Session Facilitator:** Bob Makinson
1:30 – 1:50pm	Strategic goals, needs, and options for resistance breeding and related ex situ work	Richard Sniezko
1:50 – 2:10pm	The Australian perspective: facilities, expertise, and potential species	Geoff Pegg and Karen Sommerville
2:10 – 2:30pm	The New Zealand perspective: facilities, expertise, and potential species	Grant Smith and James McCarthy
2:30 – 3:00pm	**Afternoon tea**	
3:00 – 4:00pm	**Workshop: Conservation and Research gaps and the way forward** Workshop General Discussion: 1. Goals 2. Expertise 3. Facilities 4. Priority Species	**Session Facilitator:** Bob Makinson
Day 3 Conclusion and Conference Wrap Up Summary		