Myrtle Rust Science Plan

Prepared by the Myrtle Rust Strategic Science Advisory Group

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Introduction

Myrtle rust in New Zealand

Myrtle rust (*Austropuccinia psidii*) is a serious fungal pathogen that has harmful and potentially deadly effects on plants in the myrtle (Myrtaceae) family. Myrtle rust was first detected in Aotearoa New Zealand in 2017, and has the potential to affect multiple ecologically, economically, and culturally significant taonga tree species – pōhutukawa, rātā, and mānuka are all in the myrtle family.

It is not yet known how myrtle rust will behave in New Zealand's landscape and climate, or how this disease will affect New Zealand's unique environment, and our many endemic myrtles and associated ecosystems. It has the potential to have impacts at both localised and landscape scales, across the majority of New Zealand.

Internationally, myrtle rust has had significant impacts on species of commercial and ecological importance. It has never been eradicated from any country, despite significant efforts, and can easily spread via many pathways, particularly windborne spores. In Australia, the 2010 arrival and subsequent spread of myrtle rust has affected more than 350 species. Impacts include localised extinction of once common species, further reduction in the distribution of threatened species and, more recently, changes in plant community composition.

After myrtle rust became established in Australia, New Zealand began to draw on the body of international research and initiate its own research and activities to prepare for the likely arrival of myrtle rust. This included a concentrated effort to begin to collect and preserve germplasm from New Zealand myrtle species; developing tools for disease diagnostics; analysis of potential environmental and economic impacts; risk analyses; climate modelling; and offshore investigations into host susceptibility.

When myrtle rust was detected in New Zealand in 2017, a Strategic Science Advisory Group (SSAG[1]) was formed to identify and prioritise immediate research needs. Government provided an initial $3.7 million for the urgent operational research. This (Phase 1) research has added to earlier research, particularly in including a stronger focus on social and cultural research. At the time of writing this Science Plan, Phase 1 research projects were in their final stages.

New Zealand has a unique bicultural approach for responding to biological threats, with the Crown working in partnership with Māori, consistent with obligations under the Treaty of Waitangi. Māori are kaitiaki (guardians) of New Zealand's taonga (treasures) and have statutory roles in the management of natural resources. Consistent with the above, there is an absolute commitment, expressed throughout this plan, to working in partnership with Māori.

This science plan supports the New Zealand Myrtle Rust Strategy 2019-2023 and its vision to ensure *the mauri of myrtle plants and dependent ecosystems is safeguarded and sustained*. It will help deliver the key performance indicator *myrtle rust research is strategically planned and aligned and*

[1] See https://www.myrtlerust.org.nz/science-and-research/strategic-science-advisory-group-members/ for a list of SSAG members and summary of the SSAG's roles and responsibilities

informs myrtle rust management. Particular focus on engagement and facilitating strong and equitable partnerships with Māori and communities will support delivery of the key performance indicator *communities, industry, whānau, hapū and iwi are actively safeguarding their myrtle plants and ecosystems*.

Why the science plan was developed

New Zealand has a narrow window of opportunity to identify ways to reduce the impact of myrtle rust on our forested, productive and urban landscapes. This Science Plan was developed to ensure that the research undertaken in response to myrtle rust is coordinated, focused on agreed science research needs, and takes into account the impact of myrtle rust on people and communities, the environment, and the economy.

How the science plan was developed

This plan was developed through an iterative and collaborative process, outlined below:

Implementation of the Science Plan

Managing myrtle rust successfully requires a nuanced approach to both research and management, that recognises that 'one size does not fit all', with targeted approaches developed to fit specific regions and communities. The SSAG intend for this Science Plan to be used as a guideline for future research, where researchers, Māori, managers and end users (including the public) work together, communicate and share at all stages of the research process.

Once approved by the Myrtle Rust Governance Group, the SSAG will work with research interests (investors and providers) to promote the plan and its implementation. The SSAG will be responsible for updating the Science Plan as needed.

Implementation of this plan will increase the likelihood of science making an impact by both encouraging and relying on:

- partnership with Māori;
- connection, alignment, and participation by end users;

- collaborative and multi-disciplinary research undertaken by a wide range of science providers and in part facilitated by National Science Challenges;
- an emphasis on science quality, peer review, and robust science processes and strong international linkages;
- appropriate and enduring investment in the priorities identified; and
- monitoring research progress and where necessary rapidly and adaptively responding to research findings to ensure best practice management of myrtle rust occurs.

Outputs generated across all of the research themes, including the Phase 1 research that is nearly complete, are essential to deliver robust management of myrtle rust that takes into account environmental, economic, cultural and social considerations.

Achieving this will be a significant challenge and the SSAG can play a role in meeting this. The SSAG is proposing (consistent, in part with the Kauri dieback Science Plan (see p.29) to:

- promote the science themes and research priorities identified in the Science Plan within their organisations and networks;
- report annually to Governance and external interests on plan implementation progress (see section: Monitoring and Evaluating Success of this Plan);
- support an annual symposium for scientists, managers and end users to discuss research progress, management uptake, insights, and other emerging needs; and
- evaluate New Zealand's capability and capacity to carry out the required research and science services for successful long-term management of myrtle rust.

How to use this Science Plan

The Science Plan provides a framework for all researchers to identify opportunities to contribute to the strategic vision of ensuring that *the mauri of myrtle plants and dependent ecosystems is safeguarded and sustained*. Scientists, research teams and research organisations are expected to use this plan to guide:

- Collaboration and co-design of research proposals and programmes based on plan priorities;
- Development of graduate courses and postgraduate research programmes;
- System approaches to delivering the science and providing the evidence base needed to manage myrtle rust.

Implementation of this Science Plan will see investment in priority areas of science as identified in the Science Plan and the uptake of the resulting new knowledge to help manage myrtle rust. Funders are expected to use this plan to understand and give effect to the priority needs for myrtle rust research. Addressing the research identified in this plan will help researchers demonstrate the likely impact of myrtle rust science research. Research and management should both be adaptive processes that make use of new knowledge as it arises to influence decision making, discontinue research and management that is not effective, and promote new approaches where necessary.

Partnering with Māori

Engagement with Māori across all areas of this Science Plan is essential, including in the development of this plan and the development of research questions. Māori have a distinct knowledge base: Mātauranga Māori, the body of knowledge originating from Māori ancestors, including Te Ao Māori (Māori world views and perspectives) and tikanga (customs). A critical aspect of science in New Zealand is the inclusion of Mātauranga Māori alongside Western scientific

methods and knowledge bases. This is likely to require dedicated funding and/or embedding of Māori researchers within programmes as applicable.

Contemporary Māori innovation/knowledge, such as the development of new Māori led whakahaere (management approaches) will be an important contribution within the overall science approach.

The value of actively engaging Māori in research to deliver biosecurity impacts is now widely recognised. During previous incursions and responses, Māori clearly articulated the need for inclusion as active participants in decision-making and implementation of plans for the management of pests and diseases. Specifically, Māori seek engagement and participation at all stages of New Zealand's response to myrtle rust. Part of that participation is the need to enable Māori-centred research, kaupapa Māori (Māori-led) research and research involving Māori, and to apply Mātauranga Māori-derived tools to protect taonga myrtle plants at risk from myrtle rust.

A strategic and high priority identified by Māori is to ensure all relevant collections of taonga myrtle plants (e.g. seed germplasm banks) are supported with kaupapa Māori research elements that address key Māori priorities, whilst maintaining cultural sensitivities, access, provenance and ownership of taonga biological materials. All seed-banking initiatives must be culturally appropriate and underpinned by mana whenua ownership agreements in response to myrtle rust.

Working with communities

Biosecurity has environmental, social, cultural and economic impacts and involves and affects all New Zealanders. Similar to the critical need to work closely with Māori across all myrtle rust research, there is therefore a need to engage effectively across all New Zealand communities.

This Science Plan was developed by the SSAG on behalf of all stakeholders and all New Zealanders. Science is required to underpin management of myrtle rust and protect New Zealand ecosystems; this plan can be used by all New Zealanders as a guide to what science will be most valuable for the management of myrtle rust.

This plan is intended to empower individuals, groups and communities, from researchers to the general public, to play a role in the science that is required. Using participatory research methods and co-design of research will be important for creating motivated communities of people. This will be facilitated by maintaining strong connections between researchers, central government and local government.

Successful engagement with communities will require:

- integrated research that facilitates learning and knowledge uptake;
- working with impacted communities to co-develop tools and approaches in a way that can help design appropriate interventions;
- facilitating sharing of new knowledge and joint understanding of the implications of that knowledge for action;
- building capacity to engage and develop partnerships in monitoring myrtle rust impacts and evaluating the effectiveness, efficiency and acceptability of response actions.-

Science themes

Five science themes have been identified, under which potential research topics are grouped and prioritised according to urgency, feasibility and importance. The relationships between the themes are described in Figure 1.

Theme E – Species conservation, disease and management, is represented as encompassing the other themes, as it will both guide and be guided by the research needs of Themes A – D. Themes A – D will be vital in informing disease control and management decisions.

Themes C and D are pivotal – they are themes in their own right but they also intersect all other themes. Te Ao Māori and social science represent research and concepts that cut across the entire Science Plan, in addition to being represented in both the Mātauranga Māori and Socioeconomic complexity and consequences themes. The research priorities are reflected in this way.

Theme E focuses both on the management of myrtle rust and evaluating the impact of management, while Theme A focuses on monitoring the impacts of the disease.

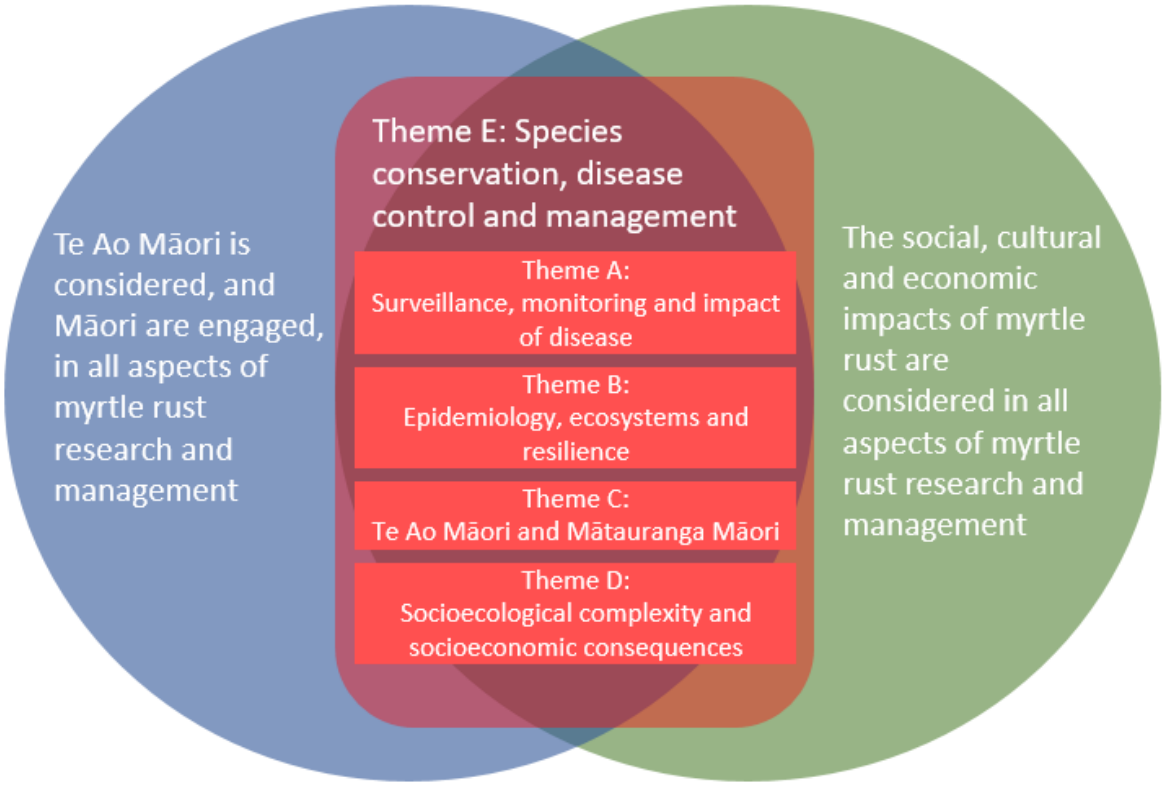

Figure 1: Visual representation of the relationships between the five Science Plan themes.

In addition to the critical research needs identified in the plan, the SSAG has identified that there is some essential infrastructure required to support this research, such as seedbank facilities and accessible repositories for data and research outcomes. The estimated costs identified in this Science Plan are for research only and do not include infrastructure.

Priorities

The research needs identified in this Science Plan are aligned with the New Zealand Myrtle Rust Strategy 2019-2023 and were developed through wide input from experts at a science workshop. Key science needs were identified and prioritised based on the following criteria:

- Strategic fit
- Net benefit – what is the overall net benefit (environmental, social, economic, cultural)?

The highest, most urgent priorities within each area were identified by workshop participants. These were further prioritised by the SSAG as highest priority (***), medium priority (**), and lowest priority (*). These priorities have been tested with workshop participants and other key experts. In setting the priorities, the SSAG drew on the outcomes of the workshop and took the following into account:

- Feasibility – is it feasible and what is the probability of success?
- Resources – what resources/capability are required – can the research be done?
- Barriers – are there any significant barriers to success and how could these be overcome?

These research needs are all priorities for further funding. While work currently underway has begun to address some of these, it is not of sufficient scale or duration to deliver the desired outcomes.

Timeframe

The estimated timeframes to conduct the research listed in the sub-themes below are defined as follows:

- Short = up to two years
- Medium = up to five years
- Long = more than five years

The timeframes indicate that we would expect outputs from research at two years, five years or beyond (from the start of the research programme), with subsequent outcomes for New Zealand myrtle species. Longer-term research will extend beyond five years with long-term outcomes. The timeframes do not determine when individual research programmes should start, and they are not timeframes for investment. They indicate how long a piece of research is expected to take.

Type of research

Strategic research is medium- to long-term underpinning research; it builds the scientific knowledge base as the foundation for new and improved tools and methods to save myrtles and improve the resilience of relevant ecosystems.

Operational research translates the outputs of strategic knowledge into practical application in myrtle rust management and myrtle conservation.

Each priority is listed as operational (O), strategic (S), or both, to indicate the nature of the research and possible funding avenues.

To this end, there is a critical need for alignment and connection between strategic research, operational research and implementation. Active and ongoing engagement with Māori and communities at all stages of research will be critical across this spectrum.

Costs

An indicative scale of investment required for each research programme listed in the themes of this Science Plan were estimated by the Myrtle Rust Strategic Science Advisory Group. This estimate is the total amount of resource required to deliver the outcomes specified in each area (the time-frames that this covers are indicated under each theme); it is not an indication of how much is actually currently available. The plan should be adaptive, with the ability to shift investment as

needs change and new findings become available. The costs estimated in this document are in addition to current investment.

Themes	Total Investment required [2]
Theme A: Surveillance, monitoring and impact of disease *Develop and implement standardised and informative myrtle rust surveillance, monitoring and impact assessment programmes for New Zealand myrtle plants and associated ecosystems.* **A.1 Diagnostics, surveillance and monitoring tools** **A.2 Monitor the emerging impacts of myrtle rust**	$4.5 million
Theme B: Epidemiology, ecosystems and resilience *To improve understanding of disease epidemiology and factors influencing disease impact, host susceptibility and ecosystem resilience.* **B.1 Understanding pathogen and environmental influences** **B.2 Understanding Myrtaceae as hosts** **B.3 Ecosystem interactions and cumulative effects**	$6 million
Theme C: Te Ao Māori and Mātauranga Māori *To ensure that Māori are able to contribute as full partners of Te Tiriti o Waitangi within myrtle rust research initiatives and participate in decision-making and activities at all levels, and that their unique contribution, including Mātauranga is valued.* **C.1 Use of Mātauranga Māori to protect our myrtles and their ecosystems** **C.2 Mātauranga based solutions and control tools to protect at risk species and ecosystems** **C.3 Kaitiakitanga of taonga Myrtaceae** **C.4 Whanaungatanga and international indigenous knowledge**	$11.5 million[3]
Theme D: Socioecological complexity and socioeconomic consequences *To understand the socioecological complexity of myrtle rust in New Zealand, better understand opportunities for promoting improved management.* **D.1. Biosecurity is a people problem** **D.2. Effective engagement at multiple scales** **D.3. Social and cultural licence**	$3.75 million
Theme E: Species conservation, disease control and management *To protect at-risk species, taonga trees and locations, and ecosystems, to develop and evaluate management tools to control myrtle rust and to protect valued myrtles and dependent ecosystems, and to evaluate the effectiveness of management actions.* **E.1 Conservation strategies** *including germplasm collection and preservation* **E.2 Control tools to protect at risk species and ecosystems** **E.3 Long term management tools to protect at risk species and ecosystems** *including selective breeding for resistance* **E.4 Management approaches, supporting infrastructure and protocols**	$13.5 million

[2] Estimated costs are for research only and do not include costs of infrastructure required to deliver or support research.

[3] This is not the full amount of funding for Te Ao Māori and Mātauranga Māori research. Estimated research costs for each theme include the estimated cost of Te Ao Māori and Mātauranga Māori aspects of each research need.

Theme A: Surveillance, monitoring and impact of disease

Context

The full impacts of a biological invasion are not apparent in the initial stages and may not become apparent for many years after the initial detection. In the case of a pathogen, the interactions between host plant susceptibility, environmental conditions and pathogen biology all affect the rate of spread, disease incidence, and severity, and therefore the ecological, cultural, social and economic impacts. To understand the impact of such an invasive disease, we need to consider the effects of any management tools on environmental, social, cultural and economic values.

New Zealand is still in the very early stages of the myrtle rust invasion curve and we do not yet have a clear view on the eventual national distribution or disease impact[4]. Diagnostics, surveillance, monitoring and impact assessment tools are already available and being used, however further research is needed to monitor the effectiveness of these and develop new and improved tools, including from a Te Ao Māori perspective. Investment in data holding infrastructure is also vital to support ongoing monitoring and evaluation of the emerging impacts of myrtle rust on New Zealand myrtle plants and broader socioecological systems. Collaboration and communication, including international and transdisciplinary collaborations, are critical for this theme.

Aim

Develop and implement standardised and informative myrtle rust diagnostic, surveillance, monitoring and impact assessment tools and programmes for Aotearoa New Zealand.

Benefits from the research

This research will provide the tools and data that are required to support the management activities set out in the myrtle rust strategy.

- Standardised surveillance and monitoring strategies and methods will:
    - Facilitate recording and reporting of disease distribution and host impacts, including Te Ao Māori perspectives
    - Provide comparable data on impacts of myrtle rust in different areas.
- Standardised method for establishing monitoring techniques, collation and reporting of data will
    - Provide cost-effective monitoring, incorporating Mātauranga Māori-based approaches, of disease progression;
    - Allow monitoring of the efficacy of management strategies/methods.

[4] Disease impact holistically captures the effects of the disease on the host and is used here instead of severity to capture effects of repeat infections over time. Disease severity is a score at a particular point in time.

Priority research needs

Priority research needs	Timeframe	Research type	Priority	Links to other themes
A.1 Diagnostics, surveillance and monitoring tools				
A.1.1. Improve existing and develop novel tools for detection of myrtle rust, and support uptake and use of tools.	Short	O	*	C, D & E
A.1.2. Improve existing or develop novel tools for determining spatial and temporal spread of myrtle rust, and support uptake and use of tools.	Short	O	*	C, D & E
A.1.3. Review existing standards for collection of biological samples in relation to myrtle rust monitoring and develop appropriate new standards where required, including regulatory and cultural approvals.	Short	O	***	C, E
A.1.4. Develop methods and approaches for rapid detection and reporting of new strains of *Austropuccinia psidii*, including monitoring for recombination/change in the pathogen population and determining the consequences of these changes.	Long	S	**	E.3.5
Total investment required for A.1: $750,000				
A.2 Monitor the emerging impacts of myrtle rust				
A.2.1. Continue to collect and define baseline data[5] that can be used to measure disease progression and change to Myrtaceae populations and dependent species over time.	Short	O/S	***	All
A.2.2. Undertake ongoing, cost effective monitoring and reporting of the above in order to understand disease progression and change over time.	Long	O	**	C & E
A.2.3. Standardise methods to determine the impact of myrtle rust and myrtle rust management actions on broader socioecological systems (e.g. urban, natural forests, riparian zones, etc.), collect baseline data and develop ongoing monitoring.	Medium	S	**	C, D & E
Total investment required for A.2: $3,750,000				
Total theme investment: $4,500,000				

[5] Baseline data here refers to information about presence and location of both host species and the pathogen, areas, species and individuals that remain free of myrtle rust, iconic/individual trees/taonga (including societal importance), and economic value of myrtle plants.

Theme B: Epidemiology, ecosystems and resilience

Context

Disease dynamics are a consequence of the interactions between host, pathogen and environment. While myrtle rust (caused by *Austropuccinia psidii*) biology has been studied in other countries, we do not yet know how this fungus will behave in New Zealand and on different myrtle plants. Myrtle rust invasion of New Zealand's native myrtle-dominated ecosystems has the potential to cause substantial changes in ecosystems and the services they provide (e.g. erosion control, carbon storage). Both the trees and these services need to be protected if our ecosystems are to continue to function and be resilient. There is a need to determine which ecosystems are more resilient to the effects of myrtle rust and what factors drive this resilience.

Comparative risk assessment will be a core component of a number of programmes in this theme. To identify the best tools for managing myrtle rust we first need to understand the disease, how it will affect our endemic and exotic species and the ecosystems that they inhabit, and how our ecosystems can be resilient to the pathogen. There is already a knowledge base in this area to be drawn on and research that is currently underway addresses some of the below research needs to some extent.

Aim

To improve understanding of disease epidemiology and factors influencing disease impact, host susceptibility and ecosystem resilience.

Benefits from the research

The research will provide the foundation for the development of robust, long-lasting management strategies.

- Understanding the environmental factors influencing disease distribution and impact will:
    - Inform surveillance, monitoring and disease management strategies, including from Te Ao Māori perspectives; and
- Understanding of native myrtle species will:
    - Create detailed and documented knowledge of the ecological and cultural significance of New Zealand's native myrtle plants to enable assessment of potential flow on effects of losing a myrtle species from an ecosystem.
- Understanding the susceptibility of host species and entire ecosystems to myrtle rust will:
    - Improve risk mapping; and
    - Provide baseline information for the development of species conservation or regeneration programmes that take account of multiple ecological and cultural considerations.

Priority research needs

Priority research needs	Timeframe	Research type	Priority /urgency	Links to other themes
B.1 Understanding pathogen and environmental influences				
B.1.1. Complete assembly and annotation of pathogen genome and comparison with other strains of *A. psidii.*	Short	S	*	A & E
B.1.2. Controlled studies to determine disease progression for different host species and how other factors, such as host susceptibility/physiology, environment and inoculum load, influence the disease cycle and severity of impact. A detailed understanding of host plant-pathogen interactions to underpin future options for management will be needed.	Long	S	**	A, C & E
B.1.3. Assessment of current risk prediction model and improvement with incoming data (including climatic risk, different strains, etc.).	Short	O	*	A, C & E
B.1.4. Investigate the number of strains of *A. psidii* that are present globally (including any present in New Zealand that have not been found yet), local constraints that may limit their spread in different areas, the threat they pose to New Zealand Myrtaceae and the pathways of entry to Zealand.	Medium	S	*	A.1.4, C & E
Total investment required for B.1: $1,500,000				
B.2 Understanding Myrtaceae as hosts				
B.2.1. Understand basic host biology and ecology, including functional role in ecosystems and identification and importance of keystone species.	Medium	S	***	A & C
B.2.2. Investigate the mechanism by which myrtle rust affects host physiology and causes damage and/or death.	Long	S	**	A & C
B.2.3. Understand how the damage to or loss of Myrtaceae individuals affects the population, and how the Myrtaceae abundance affects the ecosystem function.	Medium-Long	S	**	C
B.2.4. Comparative risk assessment of host susceptibility to inform prioritisation for germplasm collection, breeding and further research.	Medium	S	***	A, C & E
Total investment required for B.2: $2,000,000				
B.3 Ecosystem interactions and cumulative effects				
B.3.1. Understand interactions and synergies with other disturbances (fragmentation, pests, climate	Medium	S	***	A & C

change) and implication for ecosystem resilience or susceptibility.				
B.3.2. Identify factors leading to variability in species and/or site related impact of the disease.	Long	S	**	A & C
Total investment required for B.3: $2,500,000				
Total theme investment: $6,000,000				

Theme C: Te Ao Māori and Mātauranga Māori

Context

Enabling Mātauranga Māori is a strategic priority for New Zealand science; engaging Māori in research is a priority and a shared responsibility for both the Crown and Māori. Engagement and active participation of Māori across all theme areas of this Science Plan is essential. A key priority already identified by Māori during the myrtle rust response is that kaupapa Māori research approaches, and research defined and led by Māori, is an important aspect of all strategic science plans and programmes.

Additional to the kaupapa Māori research approach, is enabling opportunities to include Mātauranga and Te Ao Māori within other research areas to ensure interdisciplinary and holistic approaches. Where an integration of science and Mātauranga Māori is required to develop new knowledge in response to myrtle rust, a kaupapa of 'Iwi Kotahi Tātou' where two entities are brought together, maintains the mana of Mātauranga Māori.

Aim

To ensure that Māori are able to contribute as full partners of Te Tiriti o Waitangi to myrtle rust research initiatives and participate in decision-making and activities at all levels, and that their unique contribution, including Mātauranga Maori is strengthening myrtle rust research and management.

Benefits from the research

Measurement of myrtle ecosystem/plant health, management of myrtle rust, and ultimately elimination of long term impacts of this pathogen are enhanced by engagement of Māori and integration of Mātauranga Māori in research.

- Use of Mātauranga Māori to protect our myrtles and their ecosystems will:
    - Give effect to Māori knowledge, rights and interests (as articulated in Te Tiriti O Waitangi) in the protection against, and management of, myrtle rust; and
    - Facilitate the integration of Mātauranga Māori and kaupapa Māori methodologies as core parts of the science development process for all myrtle rust research themes.
- Development of mātauranga based solutions and control tools to protect at risk species and ecosystems will:
    - Provide new knowledge and tools; and
    - Enable iwi, hapū and whānau to develop solutions and approaches for use in their rohe.
- Kaitiakitanga of taonga myrtle plants will:
    - Maintain cultural sensitivities, access, provenance and ownership of all taonga biological materials;
    - See the development of culturally appropriate seed-banking options underpinned with mana whenua ownership agreements in response to myrtle rust;
    - Ensure relevant collections of taonga myrtle plants (e.g. seed germplasm banks) are supported with research elements that address key knowledge gaps (e.g. methods to ensure New Zealand's unique taonga seeds are stored correctly to ensure survival and future proof against local extinctions);
- Whanaungatanga with international indigenous knowledge will:
    - Support new and strengthen existing international linkages and collaborations between Māori researchers and kaitiaki with international indigenous practitioners and researchers managing myrtle rust and other related plant diseases and health issues.

Priority research needs

Priority research needs	Timeframe	Research type	Priority	Links to other themes
C.1 Use of Mātauranga Māori to protect our myrtles and their ecosystems				
Develop mātauranga based surveillance and monitoring approaches for use by kaitiaki, land/resource managers, and environmental practitioners.	Short	O/S	***	A & E
Develop mātauranga based indicators that can be used by Māori (kaitiaki, Māori researchers) to measure disease progression changes and impacts to taonga Myrtaceae over time.	Short/Long	O/S	*	A
Using a kaupapa Māori research approach to improve New Zealand's ongoing conservation program for Myrtaceae species identified as highly susceptible to and at risk from myrtle rust.	Long	O	**	E
Develop a kaupapa Māori research approach to evaluate the impacts of other environmental stressors/pressures present in myrtle rust affected rohe that could be key factors to reduce resilience or increase susceptibility.	Long	S	**	B
Develop mātauranga based approaches to identify health and resilience of taonga Myrtaceae plants and ecosystems to reduce or resist infection and/or symptoms of disease.	Long	S	**	B
Total investment required for C.1: $3,750,000				
C.2 Mātauranga based solutions and control tools to protect at risk species and ecosystems				
Develop mātauranga based tools and approaches to treat and control myrtle rust.	Medium	S/O	**	E
Use Te Ao Māori frameworks to identify existing tools and treatments and evaluate cultural acceptability, to control disease in a variety of rohe/situations.	Medium	S/O	**	E
Total investment required for C.2: $2,500,000				
C.3 Kaitiakitanga of taonga Myrtaceae				
Enable the development of a kaitiakitanga based conservation program for kaitiaki/land managers to collect, preserve and safeguard the whakapapa of their taonga germplasm using cultural protocols and practices.	Short	O	***	E
Develop a mana whenua based regional and national-scale indigenous Myrtaceae germplasm-seed bank for the conservation and curation of taonga species using cultural and best practice protocols.	Long	O/S	***	E
Co-develop Mātauranga Māori based best practice protocols for germplasm/seed-banking	Long	O/S	***	E

conservation and curation for all New Zealand priority collections identified in Theme E.1.				
Total investment required for C.3: $5,000,000				
C.4 Whanaungatanga and international indigenous knowledge				
Connect Māori researchers/kaitiaki with international indigenous practitioners and researchers to facilitate collaborative knowledge and learning of how indigenous responses to myrtle rust (and related invasive pathogens) can be effectively managed.	Medium	S	*	D
Total investment required for C.4: $250,000				
Total theme funding: $11,500,000				

Theme D: Socioecological complexity and socioeconomic consequences

Context

Managing the myrtle rust invasion is socially and economically complex. Myrtle rust will affect all of society in New Zealand, including Māori, industry groups, businesses and the general public. There will be differing perspectives about how the disease, individual trees, industry interests and forests should be managed and the social acceptability of new tools or management options. Researchers and managers need to understand the social, economic, environmental and cultural variables and expectations that are specific to different parts of society in order to develop nuanced, targeted research and management methods that are not 'one size fits all'. The visibility of hapū/iwi as kaitiaki and rangatira needs to be maintained. Research in this area can be used to guide researchers and managers around building trust and relationships so that people have confidence in research methods and management actions and have opportunities to express concerns. Maintaining engagement over time and encouraging communication between different stakeholder groups will facilitate learning and uptake.

Myrtle rust social science undertaken has focused on response operations and what impacts have been felt in relation to engagement and social licence, and how to bring together knowledge of impact across environmental, social, cultural and economic fields of research. We now need to enable a focus on research questions that can support management actions as well as the wider engagement of communities in myrtle rust management. The international literature on the social aspects of biosecurity programmes is variable, with some areas fairly well represented and others lacking. Management of other New Zealand biosecurity incursions and responses could provide useful context and insights to understand the impact of myrtle rust on New Zealand society and the importance of empowering people to play a role in biosecurity.

Aim

To understand the socioecological complexity of myrtle rust in New Zealand in order to better understand opportunities for improved management.

Benefits from the research:

This research can inform programme decision-making to ensure it is based on sound, robust and rigorous evidence, and identify actions that individuals and communities can take to help mitigate or manage the spread of myrtle rust.

- Improved identification of key target audiences and high-risk groups will:
    - Improve understanding of the social, cultural and economic drivers and barriers to engagement (including participation in desired responses).
- Effective methodologies/models for community engagement will
    - Provide ways to incorporate a variety of knowledges into the management programme (both explicit and tacit); and
    - Define values that people ascribe to New Zealand myrtle plants and associated ecosystems; and
    - Support effective strategies for science communication.

Priority research needs

Priority research needs	Timeframe	Research type	Priority	Links to other themes
D.1. Biosecurity is a shared responsibility				
D.1.1. Stakeholder analysis to determine who, along with hapū/iwi, the key stakeholders are (including who will be affected by the disease, by the downstream impacts of the disease and by the responses to the disease), their current activities, and what actions and outcomes each stakeholder group desires and how to optimise long-term management outcomes.	Short	S/O	***	All
D.1.3. Determine values that people derive from New Zealand myrtle plants by investigating ecosystems services and developing approaches to help people express what they care about.	Short-medium	S	**	C & E
Total investment required for D.1: $750,000				
D.2. Effective engagement and empowerment at multiple scales				
D.2.2. Design of effective stakeholder engagement and involvement models to improve capability, decision making and action for a variety of situations and scales.	Medium	S/O	**	All
D.2.3. Scenario planning to understand the potential long-term outcomes of myrtle rust in New Zealand and develop different possible future scenarios, and use these to prepare New Zealand for uncertain futures.	Short-Medium	S	**	All
Total investment required for D.2: $1,500,000				
D.3. Social and cultural licence (but see also theme C)				
D.3.1. With hapū/iwi, understanding and operationalising aspects of social and cultural licence, with a focus on practicality, feasibility and acceptability of new control tools and management pathways.	Long	S/O	***	All
D.3.2. Understanding and designing pathways for improved integration of knowledge into management actions.	Medium	O	*	All
D.3.3. Develop mechanisms and processes to continue engagement to ensure the 'myrtle rust message' remains at the forefront of minds to maintain levels of interest and participation commitment.	Medium	O	**	All
Total investment required for D.3: $1,500,000				
Total theme investment: $3,750,000				

Theme E: Species conservation, disease control and management

This theme brings together critical outputs from all the other themes to help ensure that outputs are translated into management applications – in effect this theme reflects the interface between science and management and includes a "research through management" approach.

Context

Species conservation

To date, species conservation of New Zealand myrtle plants has focused on collecting and preserving seeds and tissues (germplasm). There has been inconsistency in methods and variable levels of success, with generic methods being unsuitable for some New Zealand myrtle plants. As myrtle rust spreads across New Zealand it will become increasingly important to ensure that germplasm is preserved from uninfected plants of all New Zealand myrtle plants, from a variety of locations. There is a need for integrated management of conservation efforts for all groups currently trying to conserve myrtle germplasm. This theme links strongly to Theme C. Developing and maintaining strong partnerships with Māori is a priority and management of myrtle plant conservation needs to incorporate Māori needs and aspirations. Taonga will be collected, therefore cultural agreements must be in place before collections begin. The Department of Conservation has prepared a strategy that provides guidance for collection and storage of germplasm from New Zealand myrtle plants.

Disease control and management

Myrtle rust infects a diverse range of species within the myrtle family and its recent arrival means it has yet to reach its full geographic or host range in New Zealand. At present we know very little about which species (with the exception of ramarama) and ecosystems are most under threat. Some myrtle rust control and management tools are available and are being used (for example, by nurseries and local councils). Early work has begun on examining some of these tools but there is limited understanding of their effectiveness. This theme is concerned with monitoring and evaluating the effectiveness of both tools and management. It links closely with Theme C – Te Ao Māori and Mātauranga Māori and aims to develop control and management tools together with Theme C rather than independently from it.

Current knowledge

The current state of knowledge on conservation and control options is very limited in several areas. For example, Myrtaceae germplasm collections have started, but best practice has not yet been determined. A review of chemicals that have potential to provide effective disease control has been done but none have been fully tested. Cultural, social, economic, legal and environmental risks for control and management tools are recognised but have not been evaluated and mitigated.

Aim

To protect at-risk species, taonga trees and locations, and ecosystems through preservation of germplasm; to develop and evaluate management tools to control myrtle rust; and to evaluate the effectiveness of management actions.

Benefits from the research

This research will help prevent the extinction of iconic species and protect at risk species and ecosystems, and taonga trees and locations.

- Collection and preservation of germplasm will:

- Ensure that there is a reservoir of germplasm for potential breeding and material available for future work should infection and health risks prove unmanageable in the wild, while ensuring that Māori rights around intellectual property are secured.

- A suite of fully investigated management tools and approaches will:
  - Help ensure sustainable, long-term management approaches;
  - Help protect taonga/iconic trees and locations;
  - Prevent physical, aesthetic and ecosystem damage to coastal and urban landscapes dominated by myrtle plants;
  - Reduce loss to commercial crops such as mānuka;
  - Help provide tools that are culturally appropriate and where possible informed by Mātauranga Māori.
- A better understanding of effectiveness of actions will:
  - Assist with adaptive management of myrtle rust and its negative impacts;
  - Facilitate public understanding and perception of management actions;
  - Help provide hapū, whanau and Iwi knowledge about different management options that can then be considered within a Te Ao Māori context.

Priority research needs

Priority research needs	Timeframe	Research type	Priority	Links to other themes
E.1 Conservation strategies				
E.1.1. Improve conservation for Myrtaceae species by ensuring we have cultural licence, along with suitable and effective methods and protocols for collecting and preserving germplasm of all Myrtaceae species.	Short	O	***	C & D
E.1.2. Develop Myrtaceae germplasm conservation and curation best practice protocols (e.g., seed banking, cryopreservation) appropriate at mana whenua, regional and national scales.	Long	O/S	**	C & D
Total investment required for E.1: $2,000,000				
E.2 Control tools to protect at risk species and ecosystems				
E.2.1. Identify existing tools and treatments and evaluate environmental, social and cultural acceptability, to control disease in a variety of environs/situations.	Medium	S/O	***	All
E.2.2. Determine off-target and environmental impacts and benefits of fungicides (including biofungicides), incorporating expert judgement and community perspectives.	Short	S	**	All
Total investment required for E.2: $2,500,000				
E.3 Long-term management tools to protect at risk species and ecosystems				
E.3.1. Develop novel tools to treat and control myrtle rust based on mātauranga and other knowledge, while considering social and cultural acceptance of them.	Long	S	***	A, C & D
E.3.2. Develop a resistance selection and breeding programme, with a focus on hosts most at risk.	Long	S	**	B, C & D

E.3.3. Review genetic approaches to management of myrtle rust and the risks and benefits of these approaches. Evaluate science, cultural, social, economic, legal and environmental risks.	Short	S	**	C & D
E.3.4. Determine the effect of current and potential site manipulation, i.e. within- and between-species diversity or susceptible host removal, on overall disease severity.	Long	S/O	**	B & C
E.3.4. Determine role of sexual reproduction in adaptability of myrtle rust and impacts for management.	Long	S	*	B
Total investment required for E.3: $6,000,000				
E.4 Management approaches, supporting infrastructure and protocols				
E.4.1. Develop tools, practices and protocols to minimise risk of spread through human assisted pathways (e.g., nurseries, landscapers, contractors)	Short	O	*	A & D
E.4.2. Develop performance measures and decision support tools for assessing impact and effectiveness of myrtle rust management tools, approaches and protocols.	Short-medium	O	***	A & C
E.4.3. Produce good practice protocol guides to manage myrtle rust that incorporates information from various knowledge sources (scientific, practice-based, local and indigenous knowledge).	Short	O	**	A, C & D
E.4.4. Develop guidelines to manage specific taonga areas, species and individuals.	Medium	S/O	*	A & C
Total investment required for E.4: $3,000,000				
Total theme investment: $13,500,000				

Monitoring and evaluating the success of this science plan

The Science Plan provides a framework for integrating the findings of all the research themes to inform the management of myrtle rust across New Zealand. This plan is designed to support the direction and strategic goals of myrtle rust management. The science identified in this plan, when undertaken, will have significantly advanced our understanding of the impact of myrtle rust on New Zealand's myrtle species, environment, people and economy and identify approaches to reduce the harmful effects of this disease.

The implementation of this plan will be overseen by the Strategic Science Advisory Group and is subject to suitable resources for investment in science being available. Progress in achieving this plan will need to be tracked in order to capitalise on new knowledge and adaptively adjust future research priorities. To achieve this, the SSAG intends to initiate the following list of deliverables.

Deliverable	Audience	Timeframe
Create a page on the myrtle rust website dedicated to the Myrtle Rust Science Plan and tracking its implementation.	SSAG members, researchers, Mātauranga Māori experts, managers and key stakeholders	In place by 30 June 2019
Maintain a publicly accessible database of funded science projects (including outputs and data) relevant to myrtle rust (irrespective of funding sources).	SSAG members, researchers, Mātauranga Māori experts, managers, key stakeholders and the general public.	In place by late 2019
Ensure key outputs from projects are profiled on the myrtle rust science plan webpage and via other relevant communication processes.	SSAG members, researchers, Mātauranga Māori experts, managers, key stakeholders and the general public.	Updated as outputs are finalised
Support an annual symposium for scientists, managers and end users to discuss research progress, management uptake, insights, and areas for reflection, learning and new work.	SSAG members, researchers, Mātauranga Māori experts, managers and key stakeholders	Annually
Evaluate the need for revision of this science plan, including assessing New Zealand's capability and capacity to carry out the required research and science services for successful long-term management of myrtle rust.	Myrtle Rust Governance Group, SSAG members, researchers, Mātauranga Māori experts, managers and key stakeholders	2021