Risk Assessment and Ecosystem Impacts

Milestone 1: Data description.

June 2023

m.e research

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Executive Summary

This progress report provides an update on the Risk Assessment and Ecosystem Impacts project, under RA4 of New Zealand's Biological Heritage National Science Challenge. The objective is to assess the impacts of Myrtle Rust caused by the pathogen *Austropuccinia psidii* and Kauri Dieback caused by a microscopic water mould called *Phytophthora agathidicida*. To achieve this, we will use cost-benefit analysis and build on previous research. This progress report described the collection of data to support future analysis and presents key findings to date.

To gather data, a combination of methods has been employed. For Myrtle Rust data five nurseries were interviewed face-to-face, and an additional two nurseries were interviewed over the phone to explore the impact of the disease on plant propagation, as this is where its impact will be greatest. Interviews provided insights into the challenges faced by nurseries and the financial impact of Myrtle Rust. It was found that nurseries in warm areas, where the disease is prevalent, avoid growing the most sensitive species and can incorporate Myrtle Rust control into their regular spray operations.

In addition to the nursery data collection Myrtle Rust data was collected from weather stations through an online Myrtle Rust risk tool[1], chemical cost assumptions were verified with agrichemical producers and retailers, and information on Myrtle Rust impacts on nurseries was gathered from a previously completed and closely related survey undertaken by Scion.

The future stages of the Myrtle Rust research will compare two disease control approaches: calendar-based spraying and weather-based spraying, as outlined in previous research on Myrtle Rust risk modelling (Beresford & Wright, 2022). The calendar-based approach adheres to fixed time intervals for spraying, while the weather-based approach adapts the timing of spraying based on weather conditions as set out in the previous research study we are building on.

Kauri Dieback data comes from various sources to help quantify the economic impact of the disease and track closers in the Waitākere Ranges. There are three components to that data, monthly visitor counts, the Domestic Travel Survey, and track upgrade expenditures.

Monthly visitor counts provided by the Auckland Council offer insights into the popularity of tracks and recreational activities in the Waitākere Ranges. However, there are limitations to the visitor counts data, including disruptions affecting park accessibility, partially opened tracks, varied installation times of counters, non-compliance with track closures, and the decrease in international visitors due to border closures.

The Domestic Travel Survey conducted by the New Zealand Ministry of Tourism provides information on visitor expenditures associated with recreational activities. The dataset is only available until 2012. However, that will be accounted for with inflation adjustments to account for changes over time.

The third dataset for Kauri Dieback is information on track upgrade expenditures for Kauri Dieback management from Auckland Council. The project will use these expenditure reports to estimate the

[1] https://nzppi.metwatch.nz/

financial investment in track improvements and disease mitigation. The data includes capital and operational expenditures related to track upgrades and infrastructure works.

Those Kauri Dieback datasets will be used to develop a semi-probabilistic cost-benefit analysis framework that incorporates both direct and indirect value at risk. The analysis will assess the costs versus benefits of the different disease control strategies and explore the economic impact of Kauri Dieback and the value of preventative measures in the management of the Waitākere Ranges.

Overall, the research project aims to provide valuable insights into the impact of Myrtle Rust and Kauri Dieback on New Zealand communities. The data described is included both in the figures and table presented in this report as well as in three spreadsheets of supplementary material provided with this report; Myrtle Rust weather station data, Myrtle Rust survey data, and Kauri Dieback data.

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1 Introduction

In this report, we address two significant threats to New Zealand's native flora: Myrtle Rust and Kauri Dieback. These threats have had detrimental effects on the ecological landscape of the country and economic implications for local communities and the wider region. Myrtle Rust has spread rapidly since its discovery in New Zealand in 2017, affecting iconic species within the *Myrtaceae* family. Kauri Dieback poses a severe threat to majestic Kauri trees, causing extensive damage and eventually leading to their death. These ancient and culturally significant trees play a crucial role in New Zealand's natural heritage.

In this report, we describe data collected to investigate impacts of two diseases, focusing on Myrtle Rust impacts on nurseries and the direct and indirect impacts from Kauri Dieback on Kauri trees in the Waitākere Ranges, while exploring strategies for disease control and management.

The work presented here has been completed under the Risk Assessment and Ecosystem Impacts project, under RA4 of New Zealand’s Biological Heritage National Science Challenge.

1.1 Myrtle Rust

Myrtle Rust, caused by the pathogen *Austropuccinia psidii*, poses a significant threat to New Zealand's unique flora. This fungal disease was first discovered in New Zealand in 2017, and since then, it has rapidly spread, affecting various species within the Myrtaceae family, including iconic plants like Pōhutukawa and Mānuka. The New Zealand government and nurseries have been actively responding to the emergence of Myrtle Rust to mitigate its impact.

In New Zealand, the initial detection of Myrtle Rust occurred on Raoul Island, situated approximately 1,000 km northeast of the main islands. This remote and isolated territory served as the first indication of the pathogen's presence (Ho et al., 2019). Subsequently, in May 2017, Myrtle Rust was identified in Kerikeri, located in the North Island (Ho et al., 2019). The pathogen was confirmed to be the pandemic biotype of *A. psidii*, which had previously invaded neighbouring countries such as Australia and New Caledonia (Du Plessis et al., 2019). These findings highlight the introduction and spread of Myrtle Rust within New Zealand, posing significant concerns for local plant nurseries.

In this research project, we aim to assess the consequences of Myrtle Rust on commercial and community nurseries. We will be building upon Robert Beresford's Myrtle Rust weather-risk modelling (Beresford & Wright, 2022), and we will incorporate an economic perspective into his existing study. Our focus will be on evaluating the impact of this plant disease on nurseries and investigating strategies for disease control and management while quantifying their impacts. In this update we describe the data collected, how it was collected, and explain the design of the data collection strategy, aimed at supporting our modelling and analysis framework.

The impact of Myrtle Rust is felt most significantly by nurseries as they can have a high concentration of susceptible young host plants typically grown in close proximity with regulated moisture availability. This creates a favourable environment for the rapid spread and establishment of Myrtle Rust. Nurseries are involved in the production and distribution of plants, and the movement of infected plants or contaminated materials from nurseries is controlled under the Biosecurity Act 1993. The combination of biological interaction with legal requirements and economic impact through increased disease control costs and reduced or delayed sales makes this an excellent case study highlighting the impact of a plant disease.

1.2 Kauri Dieback

Kauri Dieback is caused by a microscopic water mould called *Phytophthora agathidicida*, which affects the roots of Kauri trees, ultimately leading to their death. The disease spreads primarily through the movement of soil containing infected material, making it difficult to control. Human activity, such as walking on infected soil or bringing it into the forest on shoes or equipment, has been a significant factor in spreading the disease.

The disease was first identified in the Waitākere Ranges in 2006, and it has quickly spread rapidly throughout the Auckland region. To combat Kauri Dieback, various measures have been implemented. These include installing hygiene stations at track entrances, DOC education campaigns to raise awareness among visitors, and the closure of high-risk areas to prevent further contamination (rāhui). Tramping tracks have been upgraded with boardwalks and gravel paths to minimise soil disturbance, and strict guidelines have been put in place to ensure people adhere to biosecurity protocols.

However, despite these efforts, the disease has continued to affect Kauri trees in the regional park. As a result, in April 2018, the Environment and Community Committee took decisive action (ENV/2018/44) by closing the forested areas of the Waitākere Ranges Regional Park, with a few exceptions, due to the escalating spread and detrimental effects of Kauri Dieback. This crucial step led to the implementation of comprehensive track and park closures, effective from May 1, 2018. There were 142 existing tracks within the regional park. Of these, nine were permanently closed, 62 were temporarily closed, and 71 tracks were scheduled for upgrades and reopening. Following the park closure and rāhui, only 25 tracks remained open to the public (Stuart Leighton, personal communication, 8 May 2023).

2 Methods

The work to date has involved learning about the current state of knowledge for Myrtle Rust and Kauri Dieback, identifying gaps in knowledge, refining our approach, and collecting the required data.

2.1 Myrtle Rust

Data on the impact of Myrtle Rust was collected through:

- Contacting nurseries,
- Weather station data,
- Previously conducted Myrtle Rust surveys,
- Contacting agrichemical producers and retailers.

2.1.1 Initial Idea

The research concept for Myrtle Rust came about as we developed our understanding of the disease, its effects, and its interactions with the environment. We came across the modelling and research conducted by Robert Beresford at Plant and Food Research regarding weather-dependent spraying programs for managing the plant pathogen in nurseries (Beresford & Wright, 2022). Robert joined our team to contribute to our research. With Robert's assistance, we refined our ideas on analysing impacts through disease control methods. Also with Robert, we established connections with the New Zealand Plant Producers Incorporated (NZPPI), who have been supporting Robert's work to date.

2.1.2 Nursery Selection

NZPPI discussed the idea with us and helped refine the research question and survey approach. They supplied a list of 64 plant producers likely to cultivate myrtles. We selected a representative sample covering various regions across New Zealand for face-to-face, phone and email-based information gathering.

2.1.3 Face-to-Face and Phone Meetings

We conducted face-to-face meetings and meetings by phone with commercial and community nurseries to refine our analysis framework. These discussions helped us gain insights into the challenges faced by nurseries in relation to Myrtle Rust and aided in developing our research.

Face-to-face interviews were in Auckland, Waikato, and Rotorua, as these were practical locations for our team to visit. Where face-to-face interviews were not possible, phone interviews were used. Phone interviews covered nurseries in the Bay of Plenty and Northland. Face-to-face and phone interviews were loosely structured around three areas, Myrtle Rust treatment and success, nursery costs and production rates, and seedling value.

A copy of the run sheet used for these interviews is in Appendix 1: Face-to-face interview run . It is worth noting that the run sheet was only a guide, and for some nurseries we deviated from the run sheet significantly, particularly for community nurseries.

Survey information was collected in the understanding it would be used for this project, and results would be presented in a manner the prevented identification of individual nurseries.

2.1.4 Weather data

Weather station data available through the NZPPI Myrtle Rust Risk tool[2] and the myrtlerust.com website[3] was downloaded to support investigation of historic weather data and its effect on Myrtle Rust risk. The daily weather and Myrtle Rust risk was downloaded for 10 locations and for a date range from January 1, 2016, to December 31, 2022.

2.1.5 Email-Based Surveys

From the face-to-face and phone interviews, our ideas were refined. We were able to narrow down the required information for our analysis framework to a targeted email survey.

To gather the data we needed, we distributed the email questionnaires to nurseries covering the length of New Zealand and supplemented this data by collecting information from online plant price lists and specifications. A copy of the run sheet used for these interviews is in Appendix 2: Email questionnaire.

2.1.6 Online data collection

Part of the framework will require the sale price of plants. To get a relationship between plant quality and its value the data was boosted by surveying publicly available price lists. We targeted nurseries advertising prices online from different regions of the country focussing on those that sold our selected myrtle species of interest.

2.1.7 Scion Survey Data

We obtained early summary data from the Scion-run survey on the impacts of Myrtle Rust. This data will assist in calibrating our framework assumptions for analysis and provides a useful cross-check for our more targeted interviews and surveys. The Scion survey is of particular use because of the high coverage and response rate that survey achieved, while focussing on Myrtle Rust impacts and costs.

2.1.8 Agrichemical data

Part of the framework will require the cost for chemical control of Myrtle Rust. Agrichemical suppliers were asked about appropriate application rate calculations and chemical pricing.

[2] https://nzppi.metwatch.nz/

[3] https://myrtlerust.com/

2.2 Kauri Dieback

Data on the provision of recreational services and the impact of Kauri Dieback in the Waitākere Ranges was collected from various data sources. These sources provide valuable insights into:

- Visitor counts,
- Domestic visitor expenditures, and
- Tracks upgrade expenditures.

2.2.1 Visitor Counts

To determine the number of visitors to the Waitākere Ranges, monthly visitor counts by park location was provided by the Auckland Council for the period spanning from 2015 to 2022 (data provided by Wayne Carlson).

2.2.2 Domestic Visitor Expenditures

Visitor expenditure numbers were acquired from The Domestic Travel Survey conducted by the New Zealand Ministry of Tourism. The data included purpose of trips, the duration of trips, modes of transport used, destinations visited, and expenditure related to domestic travel. Data was acquired for the Waitākere Ranges for the years 1999 to 2012.

2.2.3 Tracks Upgrade Expenditures

The Auckland Council's reports on Kauri Dieback management provided information on tracks upgrade expenditure to meet Kauri safety standards and investments made in mitigating the disease's spread across the Auckland Region. We collected data on financial resources allocated for upgrading the quality, accessibility, and safety of specific tracks in the network to avoid spreading Kauri Dieback from 2018 to 2022.

The following Auckland Council's reports were used as sources of information:

- Memo - Update on Kauri Dieback management (2018-2019)
- PACE 2019-2020 update on track programme - Regional and local parks
- PACE 2020-2021 update on track programme - Regional and local parks

The data acquired included expenditures related to the Kauri Dieback management program for the years 2018-19, 2019-20, 2020-21, and provisional for 2021-22. Additionally, it included specific expenditures allocated for track upgrades in the Waitākere Ranges.

3 Data description

This section describes the data acquired for both Myrtle Rust and Kauri Dieback and how they will be used in later analysis stages of this research project.

3.1 Myrtle Rust

3.1.1 Preliminary concept

The primary objective of the Myrtle Rust research is to examine its impact on the nursery community. To assess that, we will compare two approaches to disease control: weather-based programs and calendar-based programs as described by Beresford and Wright (2022). Weather-based disease control adapt the timing of operations for chemical spraying or other methods based on weather conditions that influence Myrtle Rust activity, whereas calendar-based approaches adhere to fixed time intervals. By analysing the variations in disease control costs, impacts, and seedling sales between these two approaches, we will establish a useful comparison for our research. The approach will provide valuable insights into the effectiveness of different disease control strategies in mitigating the impact of Myrtle Rust on nurseries.

3.1.2 Nursery interviews

Five nurseries were interviewed face-to-face, and an additional two over the phone. Interviews covered the Auckland, Waikato, and Bay of Plenty regions, while phone interviews also included another nursery in Bay of Plenty and included Northland. From those conversations we found that the financial impact of Myrtle Rust is marginal due to two key factors:

- There are differing sensitivities of myrtle species to Myrtle Rust, most are quite insensitive to the disease.
- Myrtle Rust risk can be controlled as part of ongoing spray operations related to other nursery species.

The most obvious impact across the nurseries spoken to was that nurseries in warm areas, where the disease is most prevalent, do not grow the most sensitive species. Generally, the loss of those species was not a significant issue for nursery managers. For many nurseries those most sensitive myrtle species made up only a small portion of sales prior to the arrival of Myrtle Rust, and those species could largely be substituted with others. However, there were exceptions. Nurseries focussed on revegetation of natural areas where those sensitive species had always been present, while still not financially affected, found the loss of the ability to produce species ecologically important to their local area particularly distressing. This was of particular relevance to community nurseries who rely on personal motivation to drive their workforce.

The expenses associated with regular Myrtle Rust control were considered insignificant. One nursery manager expressed their belief that the ongoing costs for disease control would amount to 1% or less of their operating budget. This view was influenced by the requirement for management of fungal infections across many of the plants grown by nurseries. Additionally, there is a considerable overlap in the chemical sprays used to control these fungal diseases. Consequently, determining the precise cost attributed to

Myrtle Rust becomes difficult, and the allocated expense would be minimal. Because, even in the absence of Myrtle Rust, the application of these sprays in the nursery would still be necessary.

Where costs became significant was when an incursion happened. Of the 7 nurseries spoken to 6 mentioned having had Myrtle Rust present previously. There were a range of responses to incursions. The most severe response was closing the nursery, breaking their remaining annual supply contracts, and destroying the plants. The most subdued response was removing the infected part of the plant and carrying on. The reaction to incursion considered generally appropriate depended on the severity of the infection, and the number of plants affected. Whatever the response, the aim universally across all nurseries spoken to was to make sure no infected material left the nursery gate. While some were not aware of the requirements of the Biosecurity Act 1993 specifically, their expectations for their nursery to act responsibly aligned with the acts' requirements.

3.1.3 Refined concept

Building on insights from the face-to-face and phone interviews, the initial idea was developed further. An analysis framework was designed to address the significant costs associated with Myrtle Rust, particularly when an incursion occurs. The refined framework still focuses on comparing two disease control approaches: calendar-based spraying and weather-based spraying. But it includes additional costs that are considered more significant to their nursery businesses. In the refined idea for the calendar-based approach, costs are incurred from disease control operations, and the potential for a weather-driven incursion. On the other hand, the weather-based approach incurs only the costs of sprays, as the disease control timing aligns with prevailing weather conditions, we will assume no risk of incursion. Figure 1 shows the effects under consideration for both calendar-based and weather-based disease control strategies. The basis for comparison lies in assessing costs versus benefits. Specifically, the additional disease control costs associated with weather-based spraying will be weighed against the potential benefits of avoiding incursions. Through this refined analysis, we will compare the efficacy and cost-effectiveness of different disease control strategies in managing the disease's impact.

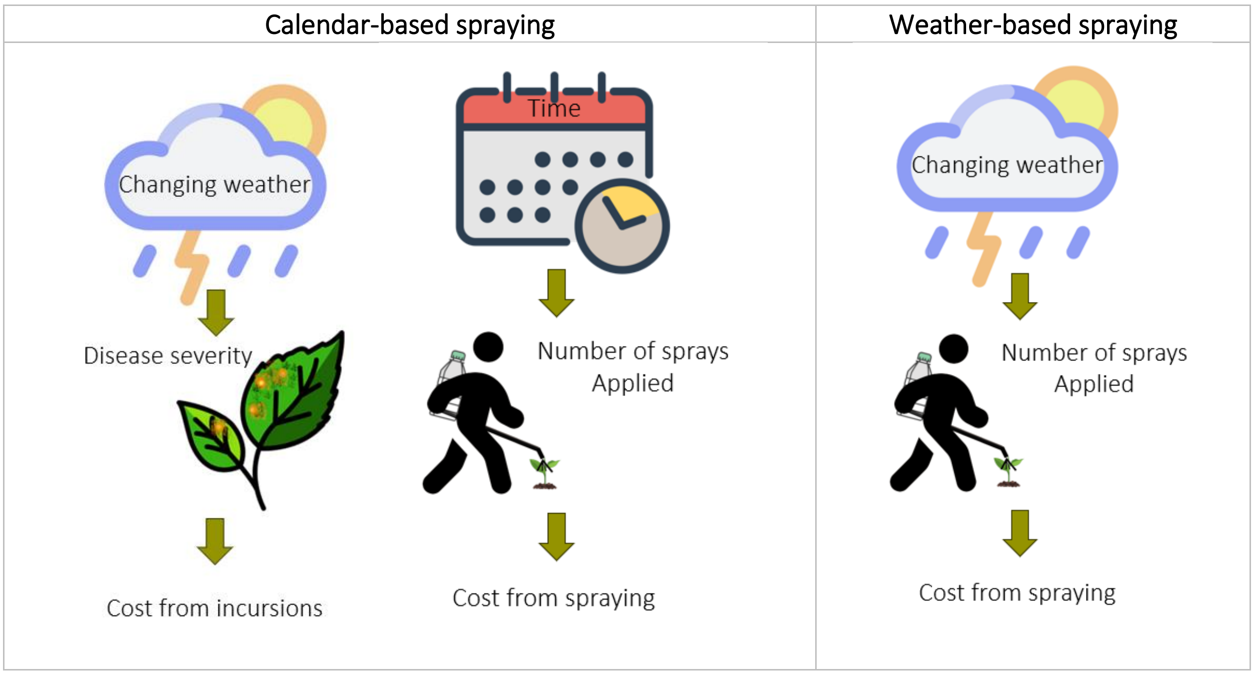

Figure 1: Sources of costs considered for the calendar-based and weather-based disease control strategies.

Based on the refined idea, we determined the importance of selecting several plant species that encompass a wide range of susceptibility to Myrtle Rust. For our study, we chose Mānuka (*Leptospermum scoparium*) as the least sensitive species, Pōhutukawa (*Metrosideros excelsa*) as a moderately sensitive species, and *Lophomyrtus* species as the most sensitive group. By including this range of myrtle species with varying sensitivities to the disease, we can focus our data collection and analysis efforts and make sure our findings are relevant across other myrtle species. The range of sensitivities for New Zealand native myrtle species is described in Beresford **(2023)**.

3.2 Weather Data

The weather data was daily weather station recordings and calculated fields of modelled Myrtle Rust risk. The downloaded data included the location of the weather stations, year of the record, day of the record, the calculated Myrtle Rust risk as described in Beresford & Wright (2022), Accumulated Myrtle Rust Risk, mean temperature, rainfall, high humidity hours, infection risk and spore risk. The locations downloaded were Kerikeri, Pukekohe, Te Puke, Rotorua, Havelock North, New Plymouth, Tasman, Canterbury, Cromwell, and Gore. Those locations were selected to cover a range of temperature and humidity climates. An example of the calculated Myrtle Rust risk is shown for four locations in Figure 2. The difference between warmer and wetter climates in the North Island with Kerikeri and Rotorua is that they have much greater Myrtle Rust risks than places in the cooler and often drier part in the South Island as shown for Gore and Cromwell. The annual cycle of higher risk in warmer wetter months is also shown across all four locations. The weather data was downloaded the NZPPI Myrtle Rust Risk tool[4] and is supplied with this report as supplementary material.

[4] https://nzppi.metwatch.nz/

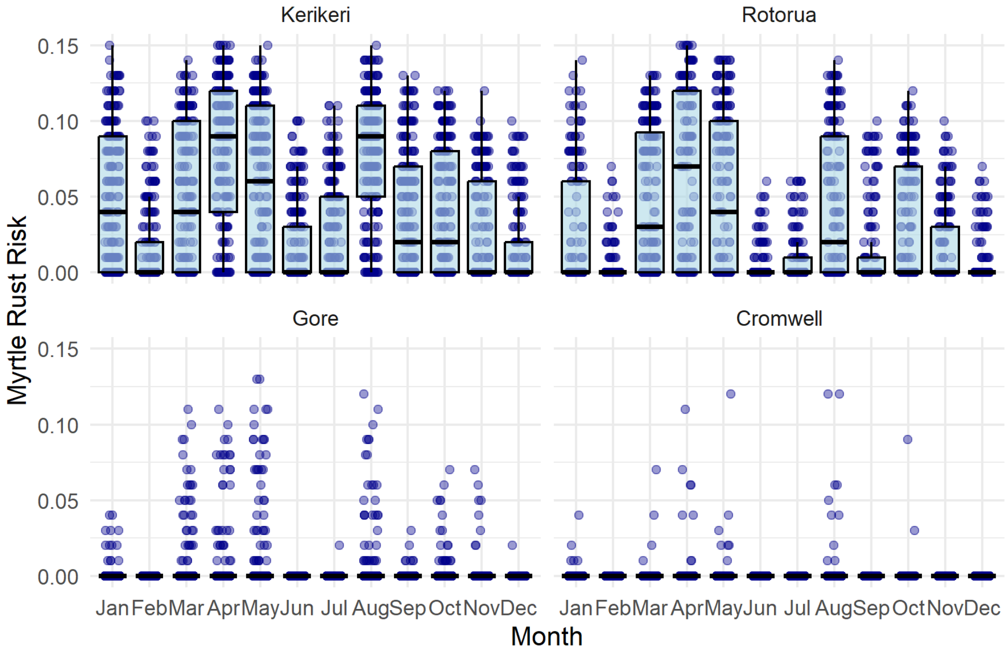

Figure 2: Daily Myrtle Rust risk for Kerikeri, Rotorua, Gore, and Cromwell, as downloaded from the NZPPI Plant Disease Management Platform. Boxplots of monthly risk are shown over the raw daily Myrtle Rust risk data.

3.2.1 Email Questionnaire

To conduct a comprehensive analysis, we identified key aspects that needed to be covered in our data collection. These aspects include determining the number of nurseries cultivating our species of interest, understanding the disease control strategies employed, examining the costs associated with plant production and disease control, and assessing the profitability of selling our species of interest. These factors will provide crucial insights for our analysis and decision-making. The email questionnaire, which was distributed to nurseries and contains the relevant questions pertaining to these aspects is shown in Appendix 2: Email questionnaire.

The questionnaire sent through email gathered information regarding key assumptions, providing valuable insights into their average values and ranges. We received completed questionnaires from four nurseries, representing locations in Auckland, Southland, and two from Canterbury. These responses included some large nurseries that make up a significant portion of the nursery industry in New Zealand. The additional data serves as a useful addition to the data collected through face-to-face and phone interviews.

3.2.2 Online Data Collection

To enhance our dataset, we conducted online data collection by extracting seedling values based on size and species from online price advertisements. A total of 16 nurseries were included in this online pricing assessment. Prices were recorded as freight-free and excluding Goods and Services Tax (GST), there was the need to adjust some advertised prices to exclude GST. The online prices were sourced from nurseries located in Auckland, Waikato, the Wellington region, Nelson Bays, Canterbury, and Otago. This online data collection process provided valuable additional insights into seedling values across a range of regions and plant specifications, expanding the scope and comprehensiveness of our data set.

3.2.3 Scion Survey Data

By accessing a previous survey conducted by Scion, we were able to complement the data we acquired. The Scion survey was particularly useful because it had excellent coverage, a high response rate, and included questions on the financial impact of Myrtle Rust on nurseries. This survey provided information on the number of nurseries that stocked myrtle plants and the quantity of plants stocked for our specific species of interest. Additionally, it provided the frequency of disease surveillance and the adoption of weather-based disease control measures among nurseries. The survey revealed the number of nurseries that have encountered Myrtle Rust within their premises, the timing of disease control activities, and the associated annual costs. Furthermore, there is information on the methods of fungicide application, the active ingredients used for Myrtle Rust control, and the specific disease control strategies employed. The findings from this comprehensive survey provided valuable context and will act as a useful cross-reference for the dataset as we use it for analysis in later stages of this research project.

3.2.4 Agrichemical Data

We contacted four agrichemical producers to gather information regarding their products and their application in relation to Myrtle Rust. All companies responded, they provided recommendations for different fungicides that generally aligned with the guidelines set forth by Beresford and Wright (2022). Notably, one company suggested the inclusion of adjuvants, such as wetters, oils, stickers, and penetrants, to enhance the effectiveness of the fungicides.

In our discussions several key points emerged. Firstly, nurseries, in comparison to other agricultural producers, tend to apply chemicals over smaller areas. Consequently, they typically purchase smaller quantities, which may result in missing out on some of the marginal price advantages enjoyed by larger agrichemical customers. Secondly, the agrichemical producers we engaged with distribute their products through a limited number of retailers. This implies that price information can be sourced from only one or two channels, thereby making it easy to get a good sample of fungicide pricing relevant to Myrtle Rust in New Zealand. For pricing we reached out to two retailers and had a reply with pricing from one. The prices we received for products from Fruitfed Supplied through PGG Wrightson are shown in Table 1.

Table 1: Brand, active ingredient, quantity, price, and applications rates supplied by Fruitfed Supplied through PGG Wrightson.

Brand name	Active Ingredient	Size	Price ($ excl GST)	Application rate (per 100L)
Saprol	190 g/litre Triforine	1 L	233.91	150ml
Flint	500 g/kg Trifloxystrobin	1 Kg	381.74	15g
Kocide Opti	300 g/kg copper hydroxide	1.5 Kg	134.78	90g
Sercadis	500 g/kg Trifloxystrobin	5 L	1,877.39	140ml

3.2.5 Myrtle Rust Combined Dataset

Figure 3. presents a bar plot illustrating the distribution of responses based on the method of data collection, including face-to-face interviews, phone calls, email questionnaires, and online price list assessments. The dataset includes a total of 27 nurseries. Among the different modes of communication, most responses were obtained through online assessments of price lists. Data from the online price lists is valuable in investigating the pricing dynamics and assessing the value of plants for our species of interest across the specifications under which they are sold. Additionally, the face-to-face interviews (F2F), phone calls, and email questionnaires provide data on the more targeted aspects of our analysis framework, allowing for a comprehensive understanding of the impact of Myrtle Rust on nurseries.

The data recorded is provided as supplementary material with this report. A description of the field included is provided in Appendix 3: Description of Myrtle Rust Survey Data. Nurseries are identified by identification numbers only in the data, rather than by name. This is to help ensure use of the data does not break any of the confidentiality assurances given to participants.

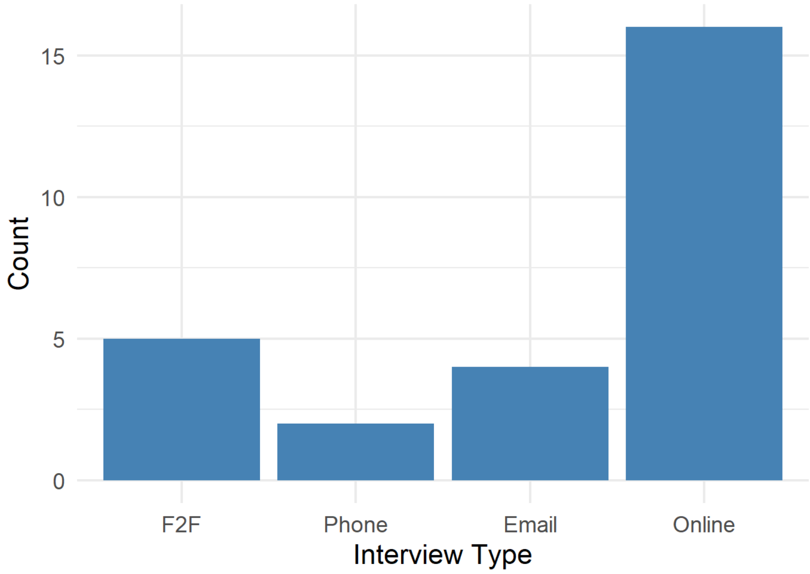

Figure 3: Counts of the Myrtle Rust survey data collected through face-to-face (F2F), Phone, e-mail, and online communication.

The data collection process encompassed a wide spatial coverage, spanning from Southland to Northland, ensuring representation across different regions. Figure 4 provides an overview of the count of responses received by region. In addition to the data from these regions, there is price information from online price lists of five nationwide retailers. This comprehensive spatial coverage is vital as it allows for the assessment of different locations that correspond to varied weather patterns. Having coverage from North to South enables us to interpolate and design scenarios for nurseries in regions where specific data is lacking, such as the West Coast of the South Island, as well as Taranaki, Manawatu, Hawke's Bay, and East Cape. By incorporating data from a range of regions, our research can provide insights that are applicable and relevant across various geographic locations.

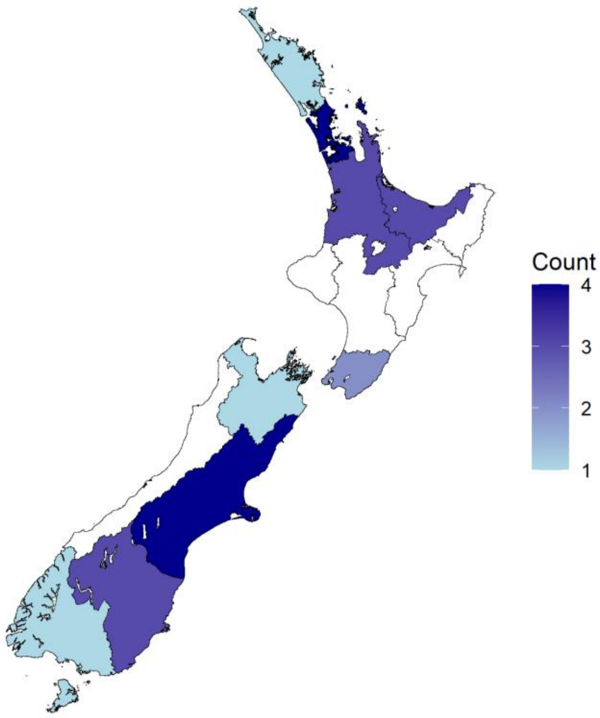

Figure 4: Spatial counts of region-specific information gathering. There are five additional nationwide retailers included through the online information gathering that are not represented in the figure.

Some key variables we targeted to be used in the framework are shown in Table 2. These variables represent aspects that will be used in analysis. The potting medium cost, at $0.24 per litre of soil, will be used in calculating the cost of incursion, where it is assumed plants will be kept longer to allow time for the disease to be irradicated, and the growth in that time requires a larger pot size. The base hourly rate, at $28 per hour, will be used in cost calculations for both disease control operations and incursion costs, such as repotting. The profit margin, at 31%, will be cost to calculate the cost of plant production, working backwards from advertised plant prices. The freight component, at 9%, will be used where required to convert reported costs to a freight free cost, and the average spray interval of two weeks will be used to set representative calendar-based spraying scenarios. In addition to the averages, the variation in responses expressed as a margin of error at the 95% confidence level in Table 2 will be used in setting scenarios for analysis in the later stages of the project.

Table 2: Key variables of interest including average values and confidence intervals.

Item	Average	Confidence (95%)	Unit
Potting medium cost	0.24	± 0.13	$/L
Base hourly labour rate	28	± 2.4	$/Hr
Profit margin	31	± 0.19	%
Freight component	9	± 7	%
Spray interval	2	± 1.4	Weeks

The sensitivity of our species of interest to Myrtle Rust has been included by asking nursery managers the number of missed sprays it would take to cause concern for each of our species of interest. The results are shown in Figure 5. It shows Mānuka is considered the least Myrtle Rust sensitive species out of the three, requiring sometimes more than 10 sprays to be missed before nursery managers become worried about Myrtle Rust infecting Mānuka plants. Conversely nursery managers become worried about infection in Pōhutukawa after much fewer missed sprays with around 2 or 3 missed sprays causing concern. The most sensitive species group which is usually not grown in Myrtle Rust areas was universally assigned a 1 by nursery managers, meaning any missed sprays would cause concern for Myrtle Rust infection. The relativities between species will be a key aspect of the analysis framework, and will enable the inclusion of Mānuka and Pōhutukawa species in addition to the *Lophomyrtus* species on which the model by Beresford and Wright (2022) was built.

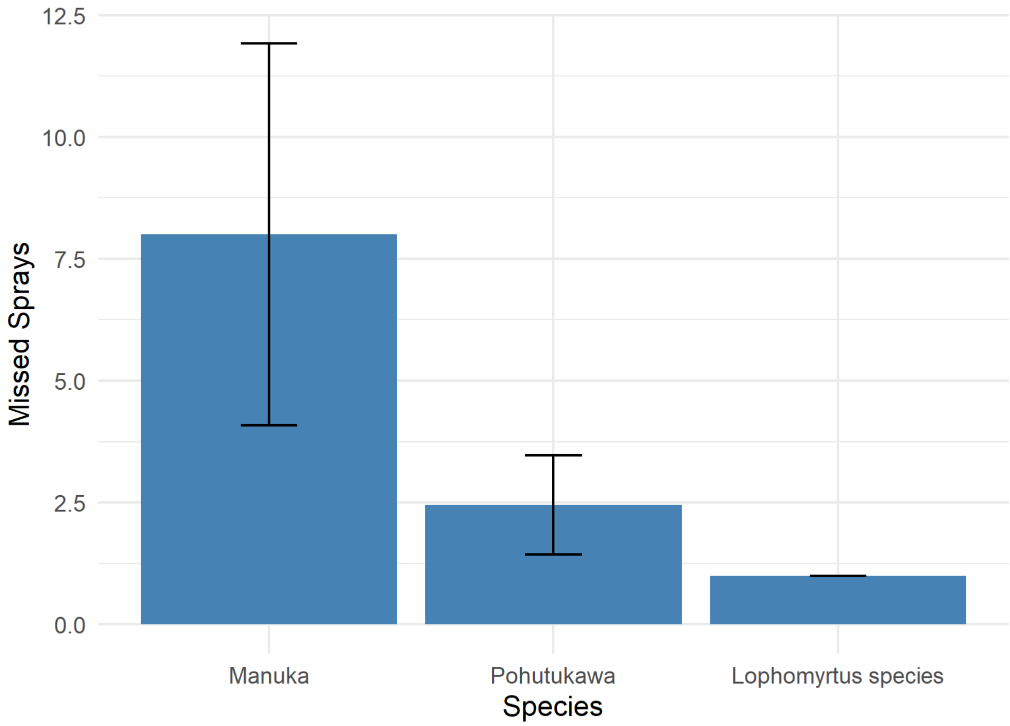

Figure 5: Perceived sensitivity to Myrtle Rust by nursery managers for our species of interest measured as the number of missed sprays causing concern for infection, with 95% confidence intervals shown.

Data on plant pricing is shown in Figure 6. There is a strong relationship between the price paid for a plant and the size of the pot in litres. Pōhutukawa prices extend much further into larger pot sizes than the other species. This is because Pōhutukawa is a popular tree in landscaping, a part of the nursery industry where large bushy trees are required. Mānuka is also used for landscaping and is provided by landscape nurseries. *Lophomyrtus* was generally not sold for landscaping as was grown for revegetation purposes in the nurseries surveyed. That is why there are no prices for *Lophomyrtus* species prices recorded at the larger pot sizes. Prediction of prices from pot size was good for the two species with data for larger pots. Adjusted R-squared values for Mānuka, Pōhutukawa, and *Lophomyrtus* plant prices from pot size were 0.76, 0.83, and 0.1 respectively. For Mānuka and Pōhutukawa where there was data to support models with good predictive power the standard errors were \$17 and \$65 respectively. The addition of plant height added no significant additional explanation of plant value.

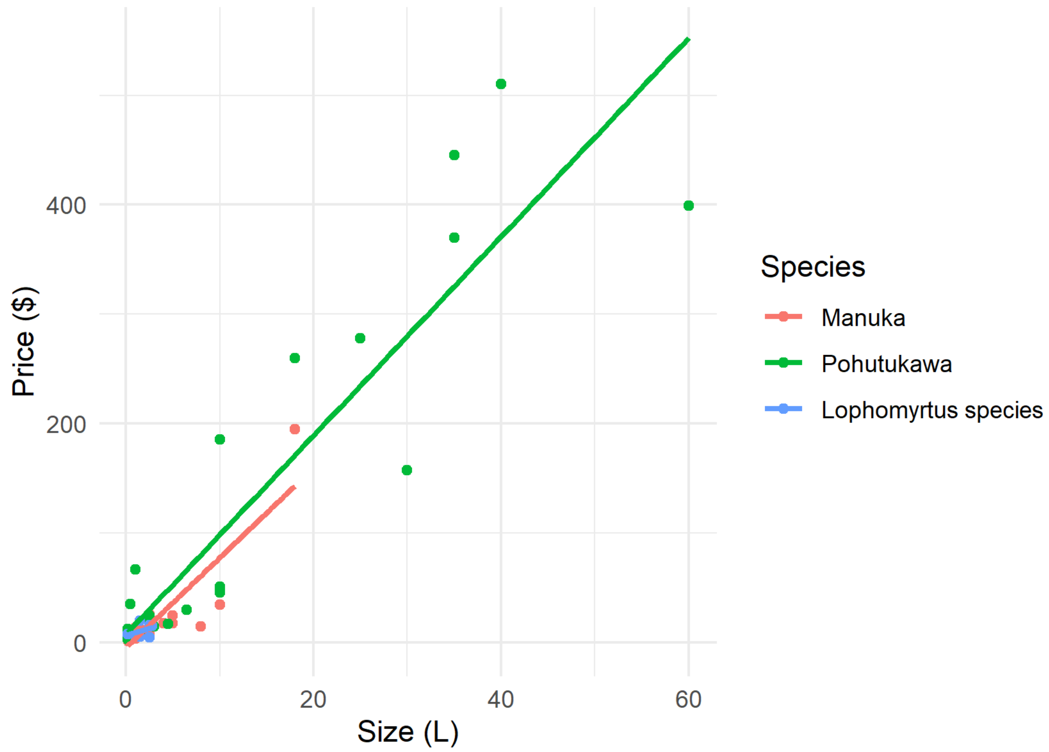

Figure 6: Relationship between the size of the pot in litres and the price of Mānuka, Pōhutukawa and *Lophomyrtus* plants sold by nurseries.

3.3 Kauri Dieback

The combination of the Kauri Dieback datasets enables a comprehensive assessment of the economic activity generated by the Waitākere Ranges tracks and allows for the estimation of the "value at risk" associated with a potential infection outbreak and subsequent track closures. The combined data including visitor counts, domestic visitor expenditure, and tracks upgrade expenditure is included as supplementary material with this report.

3.3.1 Visitor Counts

The locations considered in the visitor count data are Arataki, Cornwallis, Karamatura, Whatipu, Piha (Glen Esk), Cascades-Kauri, Lake Wainamu, Fairy Falls, Anawhata, Mt Pukematekeo, Huia Point, North Piha, Karekare, and Pae o te Rangi. The visitor count through time for those locations are shown in Figure 7. There are both seasonal variation and trends in the data. Notably, the Cornwallis track stands out as the most popular, particularly during the summer months. These counts are a crucial component in assessing the use and popularity of those tracks. By capturing the fluctuations in visitor numbers over time (pre, during and “post” rāhui), we can gain a deeper understanding of the potential economic impact of the rāhui on the recreational services offered.

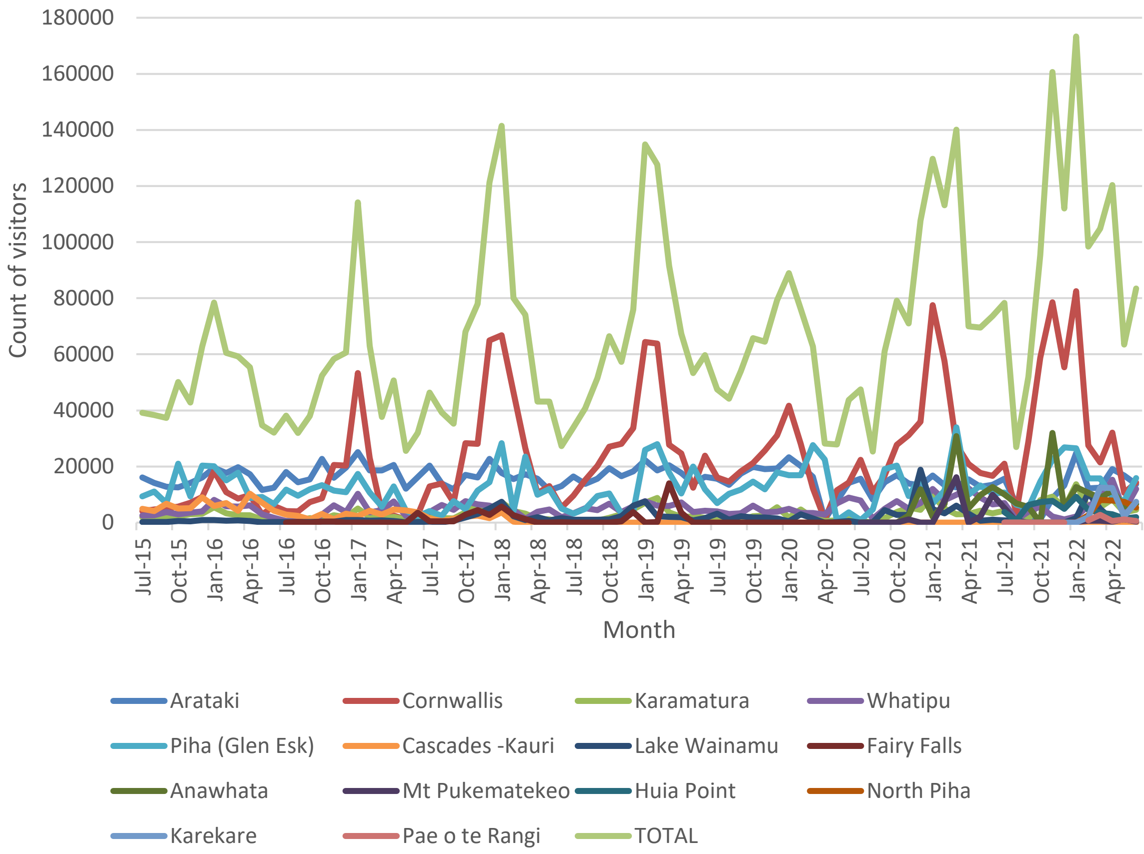

Figure 7: Monthly visitors count by location.

It is important to note that while the visitor counts dataset is a valuable input for our analysis, there are several limitations and potential uncertainties that need to be mentioned:

- Disruptions affecting park accessibility: During the timeframe under consideration, various disruptions have limited people's ability to access the park. These disruptions include Covid-19 lockdowns in 2020 and 2021, track closures for maintenance work, park closures for a few months due to 1080, and a road closure of three months caused by a slip.
- Partially opened tracks: Certain tracks within the Waitākere Ranges remained partially accessible, allowing people to engage in recreational activities in specific areas.
- Varied installation times of counters: Additional counters were introduced at different times, and not all tracks were equipped with counters. This may result in under or overestimation of visitor numbers for certain tracks. The Auckland Council conducted visits and car counts in the Waitākere Ranges carparks on an ad hoc basis, utilising their staff for this purpose.
- Decreases in counts due to rangers being out of job: Towards the end of 2021, there was a decline in visitor counts because of rangers being out of job due to Covid-19 vaccination-related issues.
- Changes in booking systems for campsites and baches: Auckland Council implemented modifications to the booking system for campsites and baches in recent years, which could impact the accuracy of visitor count data.
- Non-compliance with track closures: The data indicate instances of non-compliance with track closures due to Kauri spread, with people continuing to walk on tracks despite their closure.

- Auckland’s regional fuel tax: Another contributing factor to local visitation may be the increase in fuel prices due to the Auckland’s regional fuel tax in 2018.
- Increase in visitors after partial lifting of lockdown restrictions: When lockdown restrictions were partially lifted in Auckland, there was an observed increase in the number of visitors, possibly influenced by a statement from the Prime Minister of the time encouraging people to "go to the beach."
- Cancellations of significant events during Kauri Dieback and Covid-19 lockdowns: Some major events such as the Hillary Ultra Marathon and the West Coaster were cancelled due to Kauri Dieback rāhui and potentially other factors, which could have impacted visitor numbers.
- Significant reduction in international visitors due to border closure: Over the past three years, the number of international visitors has significantly declined due to the closure of borders.

3.3.2 Domestic Visitor Expenditures

The Domestic Travel Survey offers valuable data on visitor expenditures associated with recreational activities. By leveraging this dataset, we can estimate the financial contributions made by visitors, which further contributes to the evaluation of the economic benefits derived from the tracks.

The dataset covers visitors to the Waitākere Ranges engaged in recreation activities like walking, sport activities, and sightseeing. Expenditure was collected for the following types: accommodation, transport, alcohol, food and beverage, gambling, gifts and souvenirs, recreation/entertainment/attractions, and other shopping.

There are some limitations to consider when using the Domestic Travel Survey dataset:

- Visitors’ expenditure data is available only until 2012, as collection of the data stopped after that period. To account for this, expenditure data needs to be inflation-adjusted to reflect the current year, 2023.
- A trip may involve multiple visits on the way to a final destination. Expenditures are recorded on a per-trip basis, which may not accurately capture the total expenditure associated with each visit.
- The dataset does not include international visitors’ expenditure. International visitors are a small proportion of the total number of visitors to the Waitākere Ranges, especially considering the recent border closures due to Covid-19. Consequently, our analysis focuses on domestic visitors only.

3.3.3 Tracks Upgrade Expenditure

The expenditure data acquired covers the upgrade of tracks to Kauri safety standards throughout the entire Auckland Region, including capital expenditure on track upgrades and infrastructure works in regional and local parks, as well as operational expenditure. Operational expenditure encompasses surveillance, monitoring, treatment and research, compliance/engagement and behavioural change, and tracks upgrade for regional and local parks.

Additionally, data specifically pertaining to tracks upgrades in the Waitākere Ranges are available for the years 2019-20 and 2020-21. Analysing the tracks upgrade expenditure in the Waitākere Ranges provides an estimation of the financial investment required to reduce the spread of Kauri Dieback in the area.

Therefore, by combining these data sources, we can gain a comprehensive understanding of the economic activity generated by the tracks and the economic impacts associated with potential track closures. This analysis will provide insights into the economic benefits associated with investing in track improvements and other preventative measures against Kauri Dieback.

3.3.4 Analysis

From the datasets described the Kauri Dieback research will develop a "semi" probabilistic cost-benefit analysis for evaluating the provision of recreational services and assessing the impacts of Kauri Dieback in the Waitākere Ranges/Auckland Region. The research will draw from traditional probabilistic cost-benefit analysis in the natural hazards field and explores the inclusion of both direct and indirect value at risk.

Specifically, the research will focus on estimating the economic activity generated by visitors to the regional park, while also considering the expenses associated with track upgrades and safety measures to mitigate the spread of the disease. This estimation will serve as the "value at risk" in the event of another Kauri Dieback outbreak and potential closure of the tracks. The benefits of implementing preventive measures will be quantified as the potential avoided losses, while the costs will be determined based on the Auckland Council’s management programs.

By estimating a probability threshold that equates benefits and costs, the study will determine the optimal investment level for track improvement and mitigation measures, such as the installation of cleaning stations.

4 Conclusions

In the next stages the project will use economic analysis to focus on assessing the impact of Myrtle Rust on nurseries in New Zealand and Kauri Dieback on recreational expenditures in the Waitākere Ranges. The study will evaluate the impact of these diseases, investigating strategies for disease control and management, and assessing impact through cost-benefit analysis. This report describes a combination of data sources that together provide valuable insights to support the analysis and decision-making process for both Myrtle Rust and Kauri Dieback.

The interviews with nurseries for Myrtle Rust revealed that the financial impact of the disease may be marginal, primarily due to the differing sensitivities of myrtle species to the disease and the ability to incorporate Myrtle Rust risk into ongoing spray operations. While some nurseries had to adjust by substituting sensitive myrtle species with less susceptible ones, community nurseries focused on revegetation of natural areas experienced the loss of ecologically important species as a distressing consequence. The costs associated with regular disease control for all nurseries were considered small, as they were already part of the routine management of fungal infections.

The refined concept of the Myrtle Rust research focusses on comparing two disease control approaches: calendar-based spraying and weather-based spraying as described in Beresford and Wright (2022). By assessing the costs, impacts, and seedling sales between these two approaches, the study aims to determine the effectiveness and cost-effectiveness of different disease control strategies in mitigating the impact of Myrtle Rust on nurseries. The analysis framework will consider various factors, including disease control costs, incursion risks, and profitability, and selected plant species with different sensitivities to Myrtle Rust to ensure the relevance of the findings across many myrtle species.

The data collected for both Myrtle Rust and Kauri Dieback represents extensive datasets available for analysis. These datasets serve as a solid foundation for deriving meaningful and insightful outcomes in the subsequent stages of the research project. Specifically, the data on Kauri Dieback highlights the critical importance of addressing the disease's impacts in the Waitākere Ranges. It also highlights the economic value of recreational services provided by the tracks, emphasising the need for ongoing investment in track improvements and preventive maintenance. By incorporating these findings, the research project will contribute to the preservation of the ecological and economic benefits from Kauri in the regional park, ensuring their continuation for present and future generations.

While the data used in the analysis provided valuable insights, there are several limitations and potential uncertainties that need to be acknowledged. Disruptions affecting park accessibility, partially opened tracks, varied installation times of counters, non-compliance with track closures, and changes in booking systems are some factors that may have influenced the accuracy of the Kauri Dieback data. Furthermore, the closure of borders due to the COVID-19 pandemic resulted in a significant reduction in international visitors, impacting the overall visitor numbers and expenditures.

In conclusion, this project has made good progress in collecting data and understanding the impact of Myrtle Rust and Kauri Dieback on communities in New Zealand and providing data to support further work. The findings from this study will contribute valuable insights and provide guidance for managing the impact two important plant diseases in New Zealand.

5 References

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Beresford, R. M., & Wright, P. M. (2022). *Risk-based fungicide management for myrtle rust in nurseries* (PFR SPTS No. 22715). Plant and Food Research. https://mpi.govt.nz/dmsdocument/54247/direct

Du Plessis, E., Granados, G. M., Barnes, I., Ho, W., Alexander, B., Roux, J., & McTaggart, A. R. (2019). The pandemic strain of Austropuccinia psidii causes myrtle rust in New Zealand and Singapore. *Australasian Plant Pathology*, *48*, 253–256.

Ho, W., Baskarathevan, J., Griffin, R., Quinn, B., Alexander, B., Havell, D., Ward, N., & Pathan, A. (2019). First report of myrtle rust caused by Austropuccinia psidii on Metrosideros kermadecensis on Raoul Island and on M. excelsa in Kerikeri, New Zealand. *Plant Dis*, *103*(8), 2128.

6 Appendix 1: Face-to-face interview run sheet.

Preamble:

Our team are running a cost-benefit analysis of Myrtle Rust control in nurseries to assess the impact of the disease. We want to understand how different Myrtle Rust control options affect costs and revenues. The control options we are considering are weather-risk-based spraying, calendar-based spraying and monitoring and removal.

We have some questions about myrtle species on costs and production, seedling specifications and availability, and spray treatments and their success to help us run the analysis.

Don't worry if you don't have precise numbers available, we are just as interested in the ranges. So estimates for a minimum and a maximum will be fine.

Data is for research – only summarise ranges will be used in reporting. No nurseries will be named.

Treatment and Success:

- Have you seen the risk-based spraying on the NZPPI website?
- What's your treatment, how often are you spraying or monitoring?
- Describe how much Myrtle Rust you've had to deal with?
- What's your success rate for getting myrtle species from seed sewing through germination and to sale?
  - Mānuka
  - Pōhutukawa
  - Ramarama

- How many sprays could you miss before you might expect to see disease on the species of interest?
  - Mānuka
  - Pōhutukawa
  - Ramarama
- Do you cycle chemical active ingredients? Is it a rolling cycle, or is it by time of year?

Cost and Production:

- What are the main things that drive the cost of seedling production?
- What are the production costs for different seedlings?
  - Mānuka
  - Pōhutukawa
  - Ramarama
- What proportion of the seedling production costs is fungicide spraying?
- What makes up fungicide control costs. For example, is it infrastructure, labour, machinery, or chemicals etc?

- Can you provide those costs, possibly including chemical costs and application rates?
- How many seedlings do you grow in a year?
    - Mānuka
    - Pōhutukawa
    - Ramarama
- What are the rules around MR? Does MPI try to police the spread of MR from nurseries?

Seedling Value:

- What is the range of seedling prices for different species?
    - Ramarama
    - Mānuka
    - Pōhutukawa
- What are the important seedling specifications for your customers?
- How do those specifications affect the price you can charge?
- How long does it (would it) take to grow a saleable Ramarama, is it more than one year?

7 Appendix 2: Email questionnaire.

Seedling numbers

How many seedlings are sold in a typical year:	
In a typical year, how many seedlings of these species would you sell?	
Leptospermum scoparium:	
Metrosideros excelsa:	
Lophomyrtus species:	

Spraying

Do you spray for funguses?	
Frequency of fungicide treatment:	
If you spray for funguses, is spraying usually conducted only on weekends?	

How many spray operations could you miss before you became worried about Myrtle Rust for:	
Leptospermum scoparium:	
Metrosideros excelsa:	
Lophomyrtus species:	

Costs

Labour cost:	
Additional allowance for spraying work:	
Typical freight cost on an order:	
Cost of potting medium:	

The approximate number of plants that can be re-potted by one person per hour:

Growth time by species and height class:

		Pot volume
	0.2 (50mm)	2.5L
Leptospermum scoparium:		
Metrosideros excelsa:		
Lophomyrtus species:		

Profits

Sale price by size and species:

	0.2 (50mm)	2.5L
Leptospermum scoparium:		
Metrosideros excelsa:		
Lophomyrtus species:		
Average profit margin across those species:		

The information you provide will be used solely for the purpose of this research project, including analysis and reporting related to the specific objectives of the research programme. Only aggregated and anonymised data from multiple responses will be used in the research and published. The report, expected to be completed by January 2024, will be made publicly available, including a link provided to respondents.

8 Appendix 3: Description of Myrtle Rust Survey Data

The data recoded is saved in an excel spreadsheet. There are 5 tabs: 'Survey', 'Control', 'Mānuka', 'Pōhutukawa', and 'Lophomyrtus'. The names of the nurseries have been left out to go some way towards anonymising the information. The information was collected in the understanding it was recorded as part of the Biological Heritage National Science Challenge and would be used as part of that project and would only be reported in a way that individual nursery information could not be derived.

8.1 Survey

Each row of the Survey tab holds information about each of the 27 nurseries included in information gathering. The Survey tab has 15 columns:

- Number: A Unique identifier for each nursery. It is an integer between 1 and 27.
- Nursery type: A classification of the nursery as either 'Commercial', 'Community', 'Council', or 'Research'.
- Region: The part of the country that nursery is based.
- Interview: How the data was collected. It is a classification as either: 'F2F' (Face-to-face), Phone, Email, or Online (When price information was taken from online advertised plant listings).
- Size Total: The total number of plants sold in an average year.
- Mānuka: Boolean (Yes or No) whether the nursery sells or advertises Mānuka plants for sale.
- Pōhutukawa: Boolean (Yes or No) whether the nursery sells or advertises Pōhutukawa plants for sale.
- Lophomyrtus: Boolean (Yes or No) whether the nursery sells or advertises *Lophomyrtus* species plants for sale.
- Spraying: Boolean (Yes or No). Whether the nursery uses chemical sprays for disease control.
- Medium cost ($/L): The cost of potting medium (soil) for that nursery.
- Hourly labour rate ($/hr): The base rate they pay nursery staff.
- Margin (%): The margin the nursery makes on seedling sales.
- Freight (%): The typical component freight would make of a customer's seedling order as a percentage.
- Notes: Comments specific to that nurseries' information.

8.2 Control

Each row of the Control tab holds nursery specific information about disease control. The Control tab has 9 columns:

- Number: A Unique identifier for each nursery. It is an integer between 1 and 27.
- Method: A short description of the method of application for nurseries who use chemical sprays for disease control.

- **Rotation:** The typical length of time between sprays during peak Myrtle Rust season.
- **Mānuka missed sprays before problems:** The number of sprays missed at which point they would expect Myrtle Rust problems.
- **Pōhutukawa missed sprays before problems:** The number of sprays missed at which point they would expect Myrtle Rust problems.
- **Ramarama missed sprays before problems:** The number of sprays missed at which point they would expect Myrtle Rust problems.
- **Weekend spraying:** Boolean (yes or no). Whether or not the nursery runs it's spray program on weekends only.
- **Additional labour cost for weekend work:** The additional percentage ontop of the base wage for weekend spraying work.
- **Notes:** Comments specific to that nurseries' information.

8.3 Species specific tabs (Mānuka, Pōhutukawa, and *Lophomyrtus*)

Each row of the species-specific tabs represents a plant advertised for sale. There can be multiple records per nursery where they are selling different sizes. The Mānuka, Pōhutukawa and Lophomyrtus tabs have 6 columns:

- **Number:** A Unique identifier for each nursery. It is an integer between 1 and 27.
- **Size (L):** The size of the pot the plant is in, in litres.
- **Height (cm):** the height of the seedling in centi-metres.
- **Price ($):** The value the plant is sold for, excluding GST and freight.
- **Number sold:** The number of seedlings sold. Note, the way the survey worked this number represent the total for the species, rather than the specific plant size.
- **Time to produce (months):** The time in the nursery for that grade of plant.