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Non-market economic valuation of myrtle rust management benefits for New Zealand residents

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AERU
Agribusiness and Economics Research Unit
A Lincoln University Research Centre.
New Zealand's specialist land-based university.

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The AERU was founded in 1962 and was at the centre of early applied economics research in New Zealand. Since that time, the AERU has produced rigorous economic, market and social research for domestic and international agencies, government departments, companies and other organisations.

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August 2017

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Key Points

- The Agribusiness and Economics Research Unit at Lincoln University and the New Zealand Ministry for Primary Industries, has estimated economic values for benefits to the NZ public from myrtle rust control and management
- There are no observable market prices available that reveal what NZ residents are willing to pay for avoiding biodiversity impacts associated with myrtle rust
- A non-market valuation methodology, choice experiments, was therefore used. This involved an online survey of New Zealand residents in June 2017, using a research panel
- The survey process achieved 550 responses with good representation of key population demographics
- The choice experiment shows that New Zealanders place substantial value on protecting susceptible plants and trees from myrtle rust impacts. The average respondent's annual marginal willingness to pay was:

Myrtle rust management outcomes		Willingness-to-pay per person
Extinction of susceptible native species	Prevent **up to 3** susceptible native species becoming extinct	$21 (14,35)
	Prevent **up to 6** susceptible native species becoming extinct	$41 (32,51)
	Prevent **up to 10** susceptible native species becoming extinct	$101 (78,115)
Impacts on heritage and iconic urban and landscape trees	Restrict losses of susceptible heritage and iconic urban and landscape trees to **Moderate Level**	$38 (32,45)
	Restrict losses of susceptible heritage and iconic urban and landscape trees to **Low Level**	$74 (66,87)
Impacts on native forests	Restrict impacts on forests to **Moderate Level**	$61 (55,66)
	Restrict impacts on forests to **Low Level**	$98 (92,103)
Impacts on domestic orchards and ornamentals	Restrict impacts on domestic orchards and ornamentals to **Moderate Level**	$43 (31,52)
	Restrict impacts on domestic orchards and ornamentals to **Low Level**	$60 (48,73)
Location of myrtle rust infections	Restrict spread of disease to **Moderate Level**	$7 (-3,17)
	Restrict spread of disease to **Low Level**	$20 (-2,44)

$NZ 2017 Annual Per-Person Average (95% Confidence Interval)

1 Introduction

This report details the development and application of a Choice Experiment (CE) used to identify and measure New Zealand residents' preferences for outcomes of myrtle rust control management. The CE method was the primary tool employed to achieve our objective; to attempt to determine, in economic terms, the value of some of the non-market benefits associated with plant species at risk of myrtle rust that might accrue from national management of myrtle rust.

Myrtle rust is a serious fungal disease that has thus far been found recently (2017) in Northland, Waikato, Taranaki, and Bay of Plenty. It affects plants in the myrtle family. New Zealand is home to 350 susceptible tree and plant species including iconic species, like the native pōhutukawa, mānuka and rata, and popular introduced plants including feijoa, bottle brush and blue gum. Severe infestations can kill affected plants and have long-term impacts on flowering and reproduction, and the regeneration of young plants and seedlings. If myrtle rust becomes widespread, it may likely impact all of New Zealand's susceptible plants to some degree and we are likely to lose some plants and species in the wild, and, possibly, animal species reliant on these plants. There could be major changes to forests where myrtles are dominant species. In some places forest cover may be lost, leading to soil erosion and weed invasion. Additionally, many of these trees and plants provide benefits to individuals and the wider public in urban, productive, and natural landscapes. Loss of these plants will affect places that people use for recreation, such as Northland and Coromandel beaches, and the appearance of affected areas. Cultural values associated with species, places and individual trees are also at risk.

Designing economically efficient biosecurity management requires a consideration of the benefits and costs of management implementation. While measurement of costs is relatively straightforward to obtain through observed market transactions, a lack of corresponding market transaction data makes valuing environmental outcomes in economic terms much more difficult. The Choice Experiment (CE) method has previously been applied internationally and domestically within the environmental management arena to estimate public values of biodiversity resources. We used a CE approach involving an online survey of the general public. This report provides estimates of benefits that could be included within a Cost Benefit Analysis. The project involved collaboration between the Agribusiness and Economics Research Unit (AERU) at Lincoln University, the New Zealand Ministry for Primary Industries and the Department of Conservation.

The project comprised seven main phases.

1. Identification of outcomes for susceptible biodiversity that are related to myrtle rust management.
2. Literature review identifying approaches to CE design relevant to the objectives, particularly on the construction of generic values at a national level.
3. Development of the CE questionnaire, combining literature review findings with workshop discussion, and results of cognitive interviews with the general public.

4. Administration of the resultant CE survey to a representative sample of New Zealand residents using an online mode.
5. Analysing data employing appropriate econometric models.
6. Estimation of monetary values that residents have for myrtle rust susceptible biodiversity outcomes.
7. Reporting.

2 Method

2.1 Choice Experiment Method

The selection of economic measurement tools to value biodiversity benefits is driven primarily by the availability of appropriate data that can describe the value of management outcomes to individuals. There are no observable market prices available that reveal what NZ residents are willing to pay for avoiding biodiversity loss associated with myrtle rust. Therefore, a non-market valuation methodology is required of which Choice Experiments (CE) is appropriate[1]. The CE method simulates market observations by creating a hypothetical market scenario within a survey that enables people to indicate their preferences for changes in biodiversity outcomes associated with myrtle rust mitigation actions and the associated costs to them. In this way, a CE produces information on quantities and prices similar to what is found in observed markets which can then be analysed to measure the benefit of changes in biodiversity outcomes resultant from myrtle rust mitigation actions. They are grounded in the same Welfare Economics framework that facilitates the use of observed market prices to measure changes in the value of benefits and costs.

CEs have, for over four decades, been applied in economics to value a wide variety of goods and services such as transport, cultural heritage, environmental quality and health care. This approach has been widely applied to value environmental benefits of pest and disease management internationally[2] and has an established New Zealand literature[3].

CEs are a survey-based method in which respondents are presented with a series of choice tasks. For each choice task, respondents choose between at least two broad options. In this study, the options represent alternative scenarios for myrtle rust mitigation actions. Each option is described by a number of attributes describing biodiversity quality outcomes associated with Myrtle Rust mitigation actions. In each choice task, the combinations of attributes are systematically varied to denote different management options. Respondents are asked to choose the option with the combination of outcomes they prefer. We assume that the options chosen by respondents are what they think are best for them personally.

Statistical information derived from these choice tasks is econometrically modelled to quantify the relative importance of each biodiversity quality outcome. By including one key monetary attribute in choice tasks, the monetary value of other non-monetary attributes can be calculated. Economists express this as willingness to pay (WTP), e.g. how much I am willing to pay to have a program that avoids native biodiversity impacts

[1] New Zealand Treasury. July 2015. Guide to Social Cost Benefit Analysis. Available at http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/guide

[2]Meldrum J. et al. 2013. Heterogeneous nonmarket benefits of managing white pine bluster rust in high-elevation pine forests. J. For. Econ. 19:61–77. http://dx.doi.org/10.1016/j.jfe.2012.10.001.

Chang W. et al. 2012. Benefit-cost analysis of spruce budworm (Choristoneura fumiferana Clem.) control: Incorporating market and non-market values. J. Environ. Manage. 93:104-112. doi:10.1016/j.jenvman.2011.08.022.

[3]Tait P et al. 2017. Valuing conservation benefits of disease control in wildlife: A choice experiment approach to bovine tuberculosis management in New Zealand's native forests. J. Environ. Manage. 189:142-149. https://doi.org/10.1016/j.jenvman.2016.12.045.

associated with Myrtle Rust. We use this value as the monetary estimate of the benefit of this management outcome.

2.2 Choice Experiment Survey Design

The survey design process was initiated by developing scenarios describing several possible myrtle rust spread alternatives. The immediacy of biosecurity response information requirements, coupled with the high degree of scientific uncertainty concerning ecological effects of myrtle rust, presented difficulties in framing management options and subsequent biodiversity outcomes.

These were disseminated around the project team and were followed by a survey to individuals, seeking their understanding of control outcomes. Both these elements fed into two tele-conferences between MPI, DOC and AERU and culminated in a face-to-face workshop, purposed with identifying control outcomes to be included in the CE survey. Subsequently, a draft survey instrument was circulated within the project group for finalisation, and concurrently, was pre-tested with the general public using cognitive interviews. This process spanned 24th May to 16th June.

2.2.1 Workshop

To identify the potential range of impacts on susceptible trees and plants resultant from myrtle rust control in New Zealand, this study conducted a workshop in June 2017. Exploring and finalising the choice of attributes that describe the outcomes of myrtle rust control was undertaken primarily with the expertise of MPI, MfE and DOC staff. The aim was to agree on what ecological changes in susceptible trees and plants were likely to result from myrtle rust control and management, and how those changes could be characterised into the very simple terms required for an online survey.

The main objective of the workshop was to determine which ecological outcomes to include in the CE. Five areas of impact were identified as the ‘outcome attributes’ of myrtle rust control that would be relevant in the context of a national level survey. These are:

1. **Extinction of susceptible native species**

   Some susceptible native species could be so severely affected that there is the risk that they vanish completely from the natural environment. If this occurs, species that rely on these type of plants for food and habitat, such as insects and birds will also be affected. The loss of any native species, or the species that depend on them, will have a large cultural impact for Māori and other New Zealanders.

2. **Loss of heritage and iconic urban and landscape trees**

   Some individual trees or collections of trees have a disproportionately large amenity, social or cultural value. This includes trees that line urban streets, trees in public parks, trees lining beaches and camping grounds, and large specimen trees that may be focal points for communities. Māori place particular emphasis on individual trees with connection to important events in history or cultural traditions and stories.

3. **Impacts on forests**

   If there is a major loss of susceptible trees and plants from our native forests this would have flow-on effects on the makeup of the landscape. These effects could potentially include canopy collapse, increased erosion, and exacerbated invasion of pest plants requiring additional management. Again, damage to the health of a forest or ecosystem, or the species that depend on them, will have a large cultural impact for Māori.

4. **Impacts on domestic orchards and ornamentals**

   Many households grow feijoa trees that provide popular fruit, and also other susceptible ornamental species. Effects could include reduced harvests and the need to use fungicide sprays for feijoa trees, and removal of larger eucalyptus trees that pose safety risks. Hobbyist beekeepers also rely on the flowering of many myrtle species for honey production, including natives such as mānuka, kanuka, rata, etc., and non-native bottlebrushes and eucalypts.

5. **Location of myrtle rust infections**

   Myrtle rust fungus has the potential to spread to many parts of NZ, but will ultimately be restricted to places where the climate is most suitable. Infections may be relatively contained or could occur over large parts of New Zealand.

2.2.2 Attributes and Levels

The levels for each biodiversity attribute used in the Choice Experiment are presented in Table 1.

Table 1. Attribute descriptions and levels for choice tasks

Management attributes	Attribute levels		
Extinction of susceptible native species	10*,6,3,0		
Loss of heritage and iconic urban and landscape trees	**Severe** High death rate*	**Moderate** Trees affected but death rare	**Low** Slow loss of a few trees
Impacts on forests	**Severe** Canopy collapse, significant loss of forest and species that live there, impacts on related ecosystem services including erosion control*	**Moderate** Forest canopy intact but with some loss of susceptible trees and plants	**Low** Forest canopy intact but contains some sickly trees and plants
Impacts on domestic orchards and ornamentals	**Severe** Popular ornamentals and fruit trees die without protection*	**Moderate** Reduced yield, less resilience, die younger	**Low** Little effect
Location of myrtle rust infections	**Severe** All of North Island, Top and Western South Island*	**Moderate** Most of North Island	**Low** Raoul Island and Northland
Additional individual annual cost ($NZ)	0*,30,60,90,150		

* denotes levels of 'no myrtle rust management option' employed in each choice task (Fig. 1)

2.2.3 Experimental Design

It is not possible to present respondents with all possible combinations of attribute levels (Table 1). Instead, Experimental Design methodology is used to create combinations of attribute levels, which represent a subset of the total combinations possible, and maximise the amount of statistical information available. These combinations are formed into choice sets. Figure 1 presents an example of a choice set shown to respondents. Each choice set comprises three options, of which respondents chose their preferred option. The first option is a 'no myrtle rust management' option that represents a scenario in which biosecurity management is not expanded from current levels, and therefore no additional cost is imposed on respondents. This option is the same for all choice sets that a respondent sees, and is known as the constant base that respondents compare other options against. The other two options represent scenarios in which biosecurity management is expanded to include myrtle rust control management, and contain improvements in biodiversity outcomes for each attribute compared to the constant base option. These two management change options do impose an additional annual cost on respondents.

The study employs NGene[4] software to apply a D-efficient fractional factorial design approach[5]. Providing information on the likely values of model coefficient estimates improves this process. For the initial experimental design, we looked at similar studies for design parameters, then updated these with coefficient estimates from a model fitted to pilot survey data (n=100). The resulting updated experimental design is applied to the remaining number of respondents with each respondent answering five choice sets.

Set 1 of 5

Each column describes the outcomes of three alternative management options for myrtle rust. Based on the outcomes of each option and associated cost, which option would you prefer?

	No myrtle rust management option	Myrtle rust management Option A	Myrtle rust management Option B	More Info
Extinction of Vulnerable Native Species	10 extinctions	None	6 extinctions	
Loss of Heritage and Iconic Urbanscape Trees	High death rate	Trees affected but deaths rare	Slow loss of a few trees	
Impacts on Forests	Severe	Low	Moderate	
Impacts on Domestic Orchards & Ornamentals	Severe	Moderate	Low	
Location of Infections	All North Island, top & western South Island	All North Island, top & western South Island	Most of North Island	
Additional Annual Cost to You	None	$30	$60	
Selection	○	○	○	>>

Figure 1. Example choice set presented to respondents

2.2.4 Cognitive Interviews

Cognitive Interviews are a leading methodology for testing questionnaires during design and implementation phases. The central aim is an assessment of whether respondents comprehend questions as intended by the researcher and whether questions can be answered accurately[6]. The method involves respondents being prompted individually to respond to a questionnaire by an interviewer who asks them to think out loud as they go through the survey and tell the interviewer what is being thought about the questions and how answers are being formed. The interviewer probes in order to explore issues including interpretation of questions.

Cognitive interviews were employed to obtain feedback on draft questionnaires from a number of people in order to identify wording, question order, visual design, and

[4] ChoiceMetrics (2014) Ngene 1.1.2 User Manual & Reference Guide, Australia.
[5] Cook RD. Nachtsheim CJ. 1980. A comparison of algorithms for constructing exact D-optimal designs. Techometrics 22:315-324.
[6] Dillman DA. etal. 2009. Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method. -3rd ed. John Wiley & Sons Inc., Hoboken, New Jersey.

navigation problems. Five interviews were conducted across a mix of gender, age and occupation, each with duration of 1 to 1.5 hours. All participants found the draft survey instrument to be capable of being apprehended or understood, with only minor semantic amendments needed.

2.2.5 Survey Administration

The sample of New Zealand resident respondents was obtained from Research Now (researchnow.com), a research consultancy that provides analytical services and maintains one of the largest global databases of survey respondents. Their panel of members is paid for completed surveys. This sampling method allowed for the pre-stratification of the sample by age, gender, income, and regional location. That would not be possible if drawing a sample from the commonly used Electoral Roll which does not include most of these variables.

Prior to full launch of the survey instrument, we conducted a pilot study with a subsample of the population (n=100) in order to evaluate interconnections among questions, the questionnaire, and the implementation procedure. This confirmed that the survey instrument was functioning appropriately.

An Internet-based survey of a sample of New Zealand residents from an online panel was conducted 20th-26th June using names and contact details obtained from a database maintained by Research Now. The final sample consisted of 550 residents from throughout New Zealand.

The survey was administered using an online survey mode employing Qualtrics™ online survey software, and proprietary software for implementing CE surveys maintained by AERU. The process consisted of contact through an email invitation to New Zealand residents that contained a link to the online survey.

3 Results

3.1 Sample Characteristics

A total of 550 New Zealand residents provided responses to the survey. Table 2 describes the composition of the sample by various demographic variables, including location. To determine whether the sample is representative of the general NZ population, we statistically tested that the distribution of the observed sample demographics was consistent with that of the general population, as provided by Statistics NZ 2013 data. Table 2 indicates that the sample composition was overall a good representation of the NZ population, with only education being skewed towards higher levels relative to that of the general population.

Demographic Variable		Sample Distribution (%)	NZ Population Distribution (%)[1]
Age [p = 0.96][2]	65 years or more	21	19
	55 – 64 years	16	15
	45 – 54 years	19	19
	35 – 44 years	18	18
	25 – 34 years	16	16
	18 – 24 years	10	13
Gender [p = 0.89]	Female	55	51
Education [p = 0.00]	High school	32	50
	Trade/technical qualification or similar	19	9
	Undergraduate diploma/certificate/degree	31	14
	Postgraduate degree	16	6
	None	2	21
Ethnicity [p = 0.18]	New Zealand European / European	80	74
	Māori	15	15
	Pacific Islander	1	7
	Asian	10	12
	Other	2	1
Occupation[3] [p = 0.17]	Unemployed	7	4
	Retired	19	14
	Unpaid voluntary work	2	1
	Student	6	6
	Paid employment	53	65
	Home duties	10	8
Personal Income [p = 0.25]	Loss	2	1
	$0 - $20,000	25	38
	$20,001 - $40,000	29	26
	$40,001 - $50,000	13	10
	$50,001 - $70,000	16	13
	$70,001 - $100,000	10	8
	$100,001 or more	6	6
Household Size [p = 0.14]	One	16	22
	Two	36	34
	Three	17	17
	Four or more	17	27
Region [p = 0.53]	Auckland	20	33
	Bay of Plenty	6	6
	Canterbury	13	13
	Gisborne	1	1
	Hawke's Bay	5	4
	Manawatu-Wanganui	7	5
	Marlborough	2	1
	Nelson	3	1
	Northland	4	4
	Otago	5	5
	Southland	3	2
	Taranaki	4	3
	Tasman	1	1
	Waikato	11	10
	Wellington	14	11
	West Coast	2	1

[1] Distributions from Statistics NZ Census 2013. [2] Values in brackets are p-values for Pearson's Chi-squared test of the null hypothesis that the frequency distribution of the observed sample demographic variable is consistent with the population distribution provided by Statistics NZ Census 2013 data. A p-value less than 0.1 indicates a statistically significant difference between the distributions; p-values greater than 0.1 indicate that the demographic distribution is not statistically different to the population and therefore are representative of the general population. [3] Population distributions from 2013 Household Labour Force Survey.

Table 2. Sample characteristics

3.2 Biosecurity Perceptions and Experiences

Preferences for how susceptible biodiversity values are managed may be influenced by perceptions, attitudes, and experiences of survey respondents in relation to biosecurity and environmental resources. The survey began by asking respondents a series of questions focused on these three elements.

3.2.1 Biosecurity

- Nearly all participants (95%) agree that unwanted plants and animals can have significant negative impacts on NZ's natural environment
- However, most people have little knowledge of biosecurity issues in general (Fig. 2)

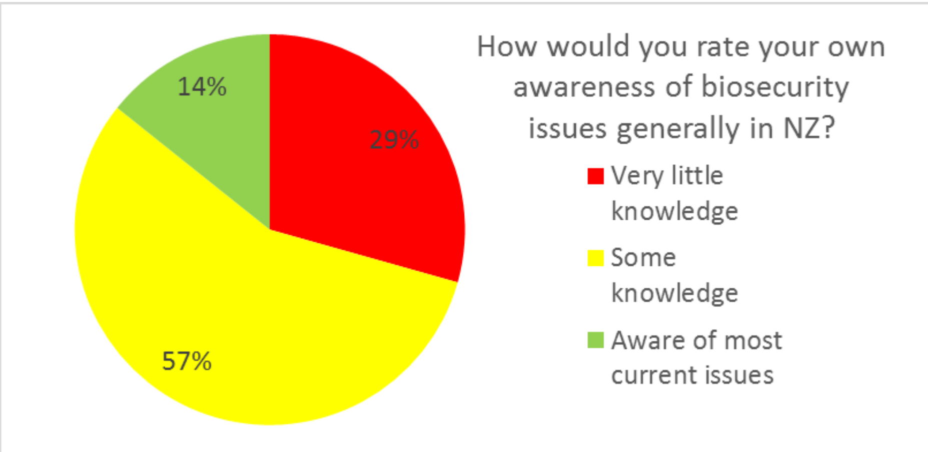

Figure 2. Biosecurity awareness

- 67% of respondents could name at least one unwanted plant in New Zealand
- 88% of respondents could name at least one unwanted animal in New Zealand (Table 3)

Table 3. Top five named unwanted plants and animals

Top five Unwanted **plants**	% Sample	Top five Unwanted **animals**	% Sample
Gorse	15	Possum	44
Old Man's Beard	13	Stoats and Ferrets	15
Ginger	4	Rats	9
Didymo	2	Snake	6
Moth Plant	2	Rabbit	5

- Biosecurity is considered most important for protection of native biodiversity, and commercial horticulture (Fig. 3)

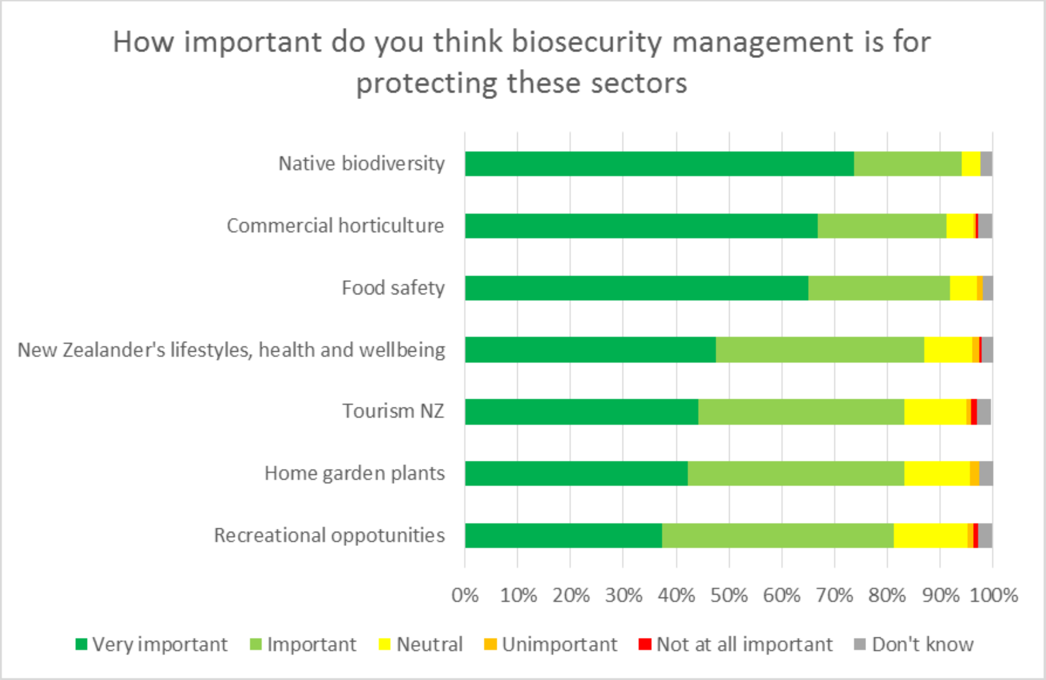

Figure 3. Importance of biosecurity management

- Over half of respondents considered biosecurity to be well managed (Fig. 4)

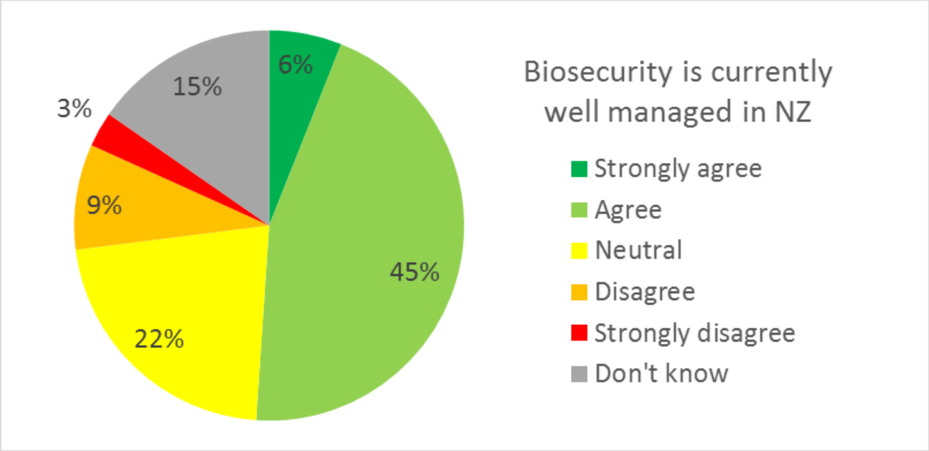

Figure 4. Management performance

- 38% of participants said that current funding for biosecurity is too low, 16% said that it is adequate, and 1% believe funding is too high.

- People believe that responsibility for biosecurity management is spread over all society (Fig. 5)

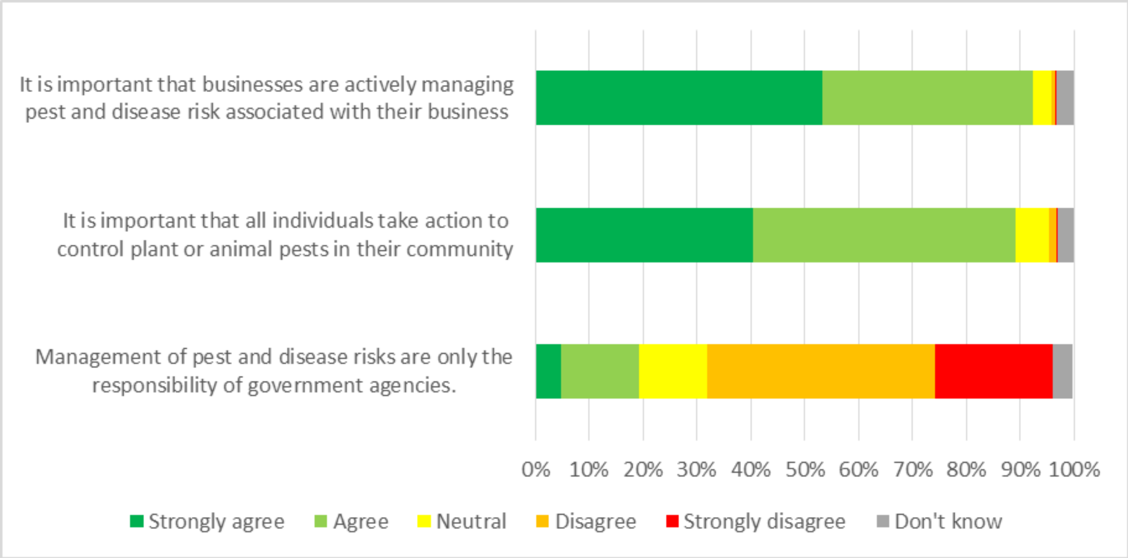

Figure 5. Responsibility for biosecurity management

3.2.2 Myrtle Rust

- Three quarters of respondents had heard of myrtle rust before receiving the survey
- Most of those respondents first heard about myrtle rust on television (60%), 16% online, 12% radio, and 8% newspaper
- Almost nine out of ten people thought myrtle rust was a serious problem (Fig. 6)

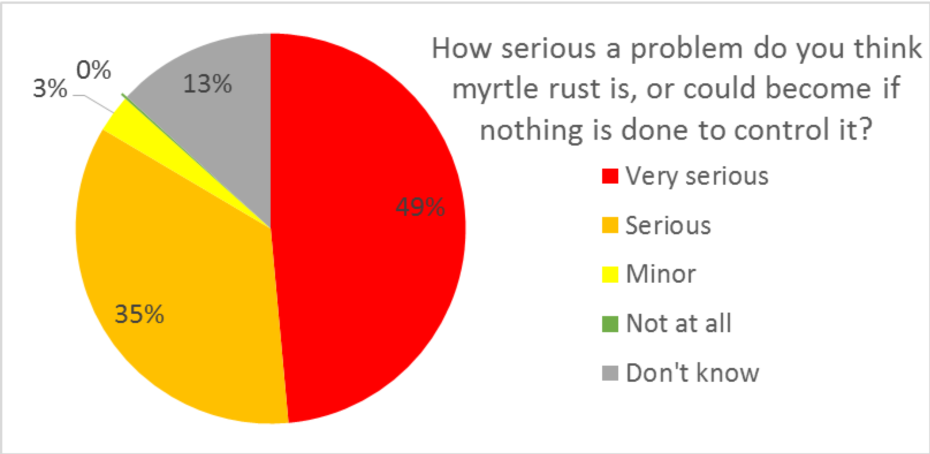

Figure 6. Seriousness of myrtle rust

- Nine out of ten people were concerned about the impact of myrtle Rust on themselves and their community
- Two thirds of respondents strongly agree that protecting susceptible native trees and plants is important
- Myrtle rust control is most important for protecting wildlife habitat, and social and cultural values (Fig 7)

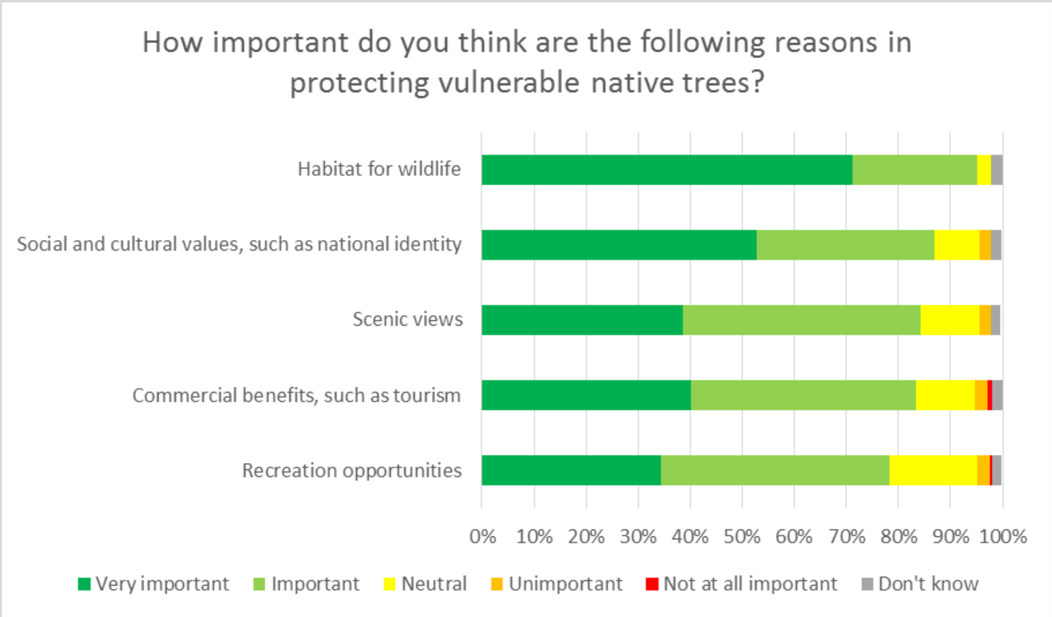

Figure 7. Importance of protection

- Protected areas including national parks are the most important areas to protect susceptible biodiversity in (Fig. 8)

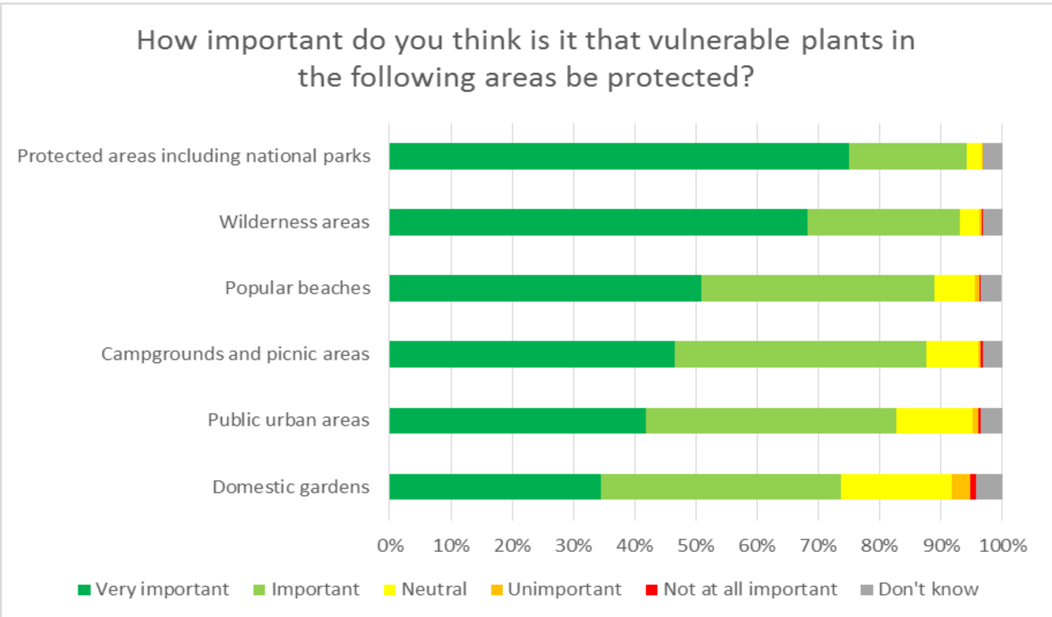

Figure 8. Important areas to protect

- 27% of respondents have been affected by a biosecurity threat (Table 4)

Table 4. Biosecurity threat experiences

Biosecurity Threat	Participants affected (%)
Fruit fly	13
Lettuce aphid	9
Varroa mite	4
Painted apple moth	4
Red imported fire ant	3
Myrtle rust	2
Dutch elm disease	2
Asian gypsy moth	2
Hadda beetle	1
Southern salt marsh mosquito	1

- The majority of those affected suffered impacts on home gardens (Fig.9)

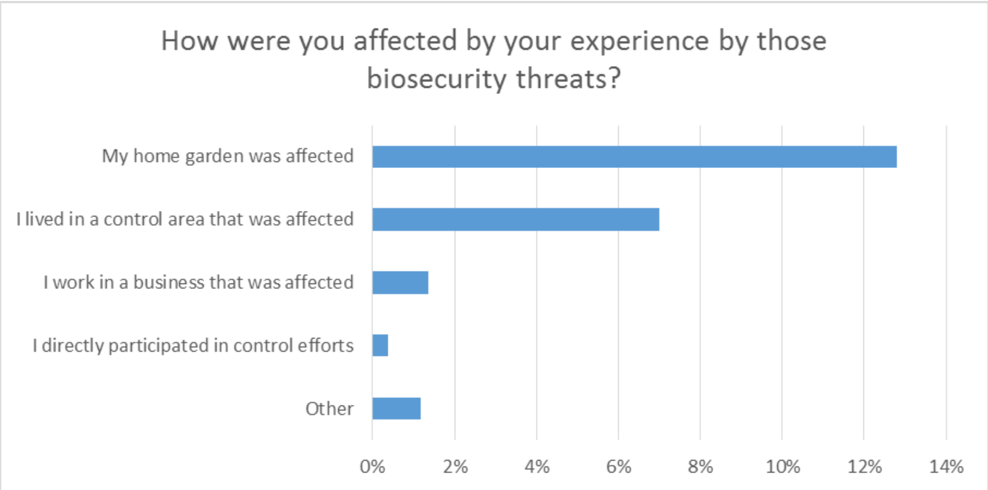

Figure 9. Biosecurity threat affect

- 36% of respondents reported that their home garden contained feijoa trees, 3% had eucalyptus trees, and 4% had other susceptible plants.
- Most of the sample had visited potentially susceptible public environments in the last 12 months (Table 5)

Table 5. Visits to susceptible environments

No. of Visits	Beach (%)	Forest (%)
0	14	31
1-5	42	47
6-12	21	12
13-52	17	8
53-100	3	1
101-200	1	0
200<	2	0

3.3 Choice Experiment Results

The outcomes associated with respondents chosen management option, and those from the other options, are analysed using a Generalised Mixed Logit (GMXL) model with an attribute non-attendance coded data set (see Appendix A for technical details). This type of model constitutes a standard contemporary methodology.

When making choices, respondents may select the 'no myrtle rust management' option in a choice task. This is usually a truthful indication of their *unwillingness to pay* for myrtle rust management. However, respondents who chose the no management option in every choice task may be exhibiting protest behavior, and therefore not truthfully revealing their preferences for biodiversity quality outcomes. Protest behaviour is relatively common in these types of surveys and is typically for reasons associated with the process of valuation such as the type of good being valued and who is being asked to pay for the good. 21% of respondents chose the 'No Management Option' in at least one choice set, with this option chosen 278 times in total (4% of all choices across the sample). Respondents who consistently chose this no cost option (5% of the sample, 27 respondents) were asked a follow up question to ascertain their reasons for being averse to paying for myrtle rust management (Figure 10).

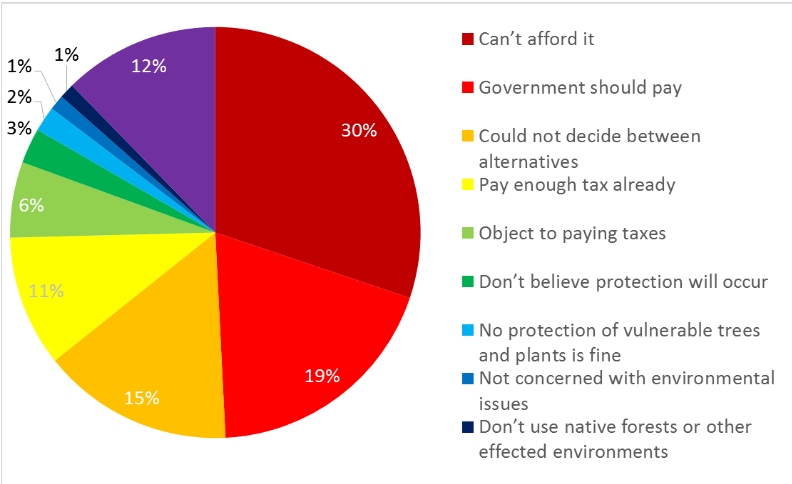

Figure 10. Reasons for 'no myrtle rust management' option choices

The majority of this group comprised protest responses (39%). These respondents considered that the government should pay (19%); they pay enough tax already (11%); do not believe changes will occur (3%), or they object to paying tax (6%). Respondents who are viewed as protest responses are excluded from statistical modeling of preferences for myrtle rust management outcomes. Respondents who indicated that they can't afford the additional expenditure are not excluded from analysis.

An underpinning statistical assumption is that all the information that a respondent sees in a choice set has a role to play in determining their choice of option. If respondents ignore some of the myrtle rust management outcomes when they select their preferred option, this assumption is weakened and requires further examination. Following each choice task, respondents were asked to indicate which, if any, of the myrtle rust management outcomes being considered did they ignore (Figure 11). We can see that each outcome is ignored to some degree. To incorporate this behavioral information analytically we incorporate a stated attribute non-attendance specification into the GMXL model (Table 6).

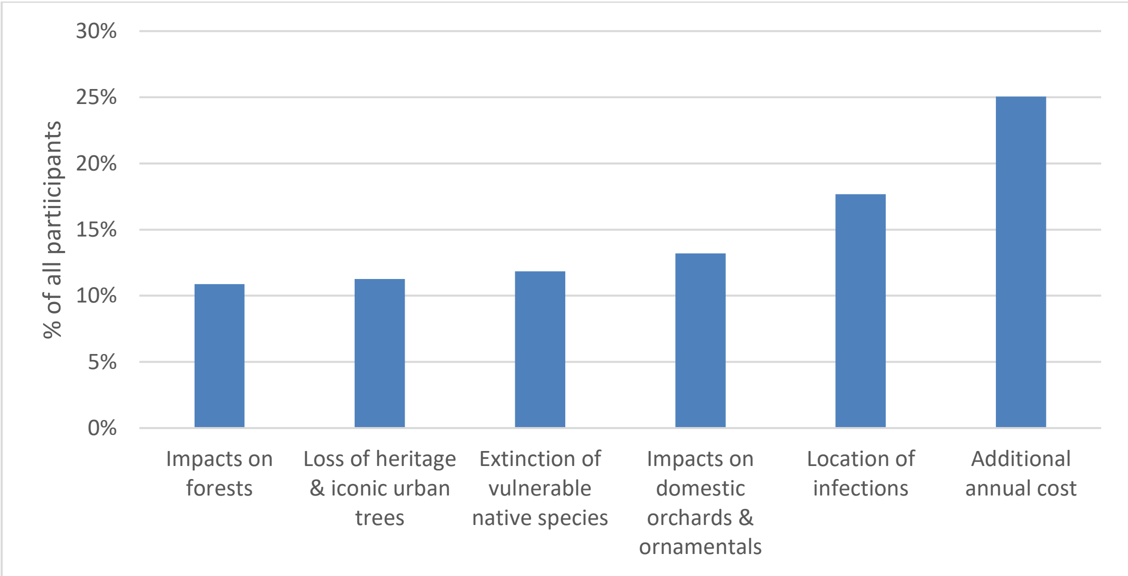

Figure 11. Myrtle rust management outcomes ignored by respondents in choice tasks

The GMXL model specified here uses a respondents' indication of choice task difficulty and understanding (Fig. 12) to identify sources of variance in the random component of utility. For example, respondents who find choices difficult have higher variability in the way they make choices compared to respondents' who do not, that cannot be attributed to the levels of the management outcomes presented to them. We find that respondents who find the choice task relatively easy to answer or that understood the choice task exhibit lower choice error. To ameliorate hypothetical bias, respondents choice data are weighted by their indication of how certain they are about their choice, with the effect of weighting down uncertain respondents, and subsequently lowering average willingness-to-pay.

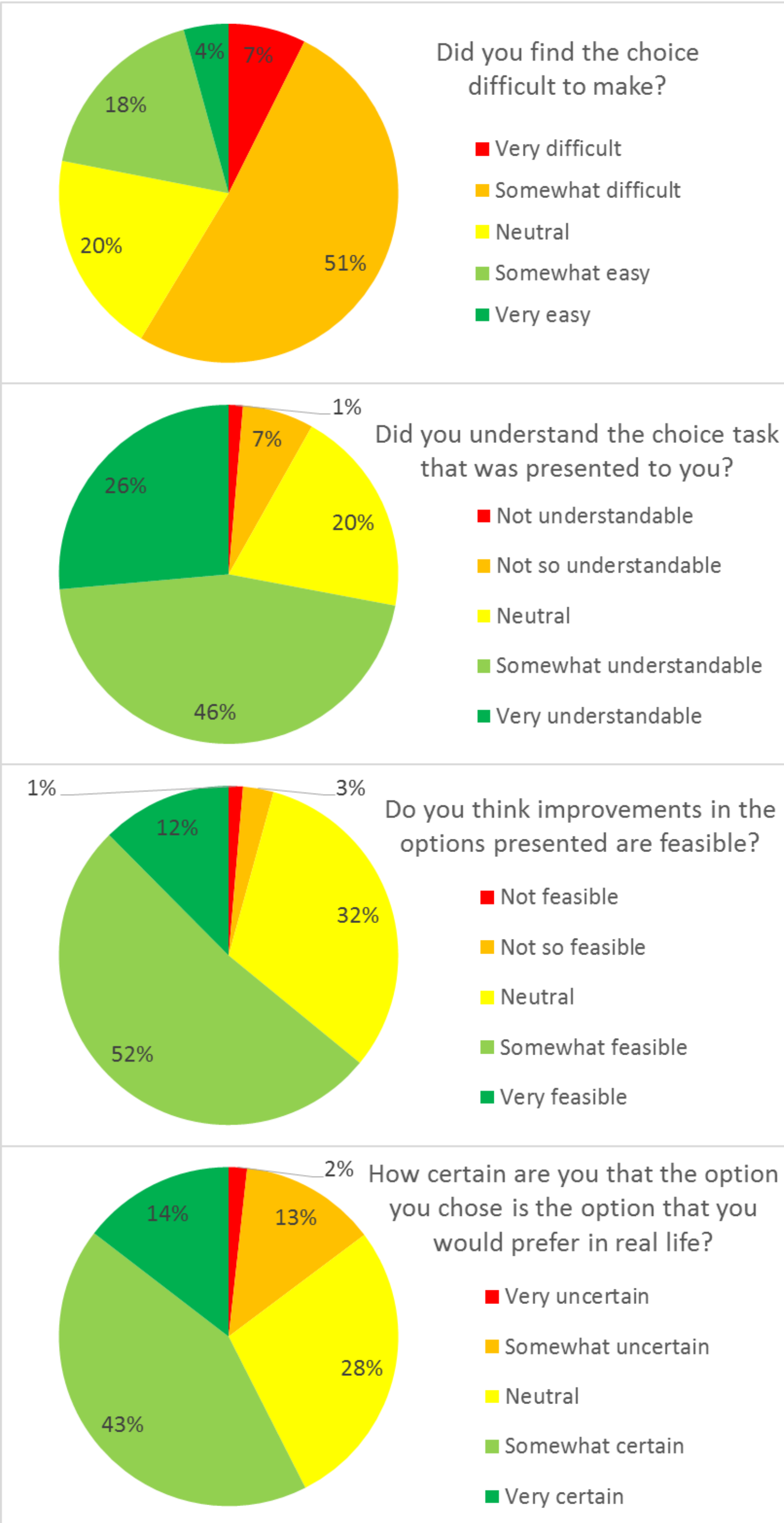

Figure 12. Choice task debriefing: difficulty, understanding, certainty, feasibility.

By conventional econometric standards the model performs well (Table 6). All myrtle rust management attributes are statistically significant, meaning that they are important factors in a resident's choice of myrtle rust management option. The model predicts how respondents choose a particular management option based on the outcomes and costs associated with that option. The parameter estimates tell us how an attribute relates to the overall utility of residents from the benefits of myrtle rust management. The model generates a distribution of parameter estimates (normal) for each random parameter with the mean reported, and the standard deviation of the distribution. A larger magnitude of the standard deviation of the distribution indicates a relatively larger degree of preference differences across respondents for that biodiversity quality outcome. For example, respondents have the most diverse preferences for reducing the impacts on domestic gardens to a low level (s.d. =1.94), meaning that some respondents prefer no improvements while others have strong preference for improvements. Estimated parameters indicate that respondents are more likely to choose a management option that provides greater protection to susceptible biodiversity, with protection of native forests having the largest influence, while they are less likely to choose options imposing greater financial contributions.

Other main findings include:

- People prefer higher levels of protection over moderate levels
- People are more likely to choose a myrtle rust management option if they perceive current biosecurity funding to be too low
- People are more likely to choose a myrtle rust management option if they are concerned about the effects on themselves and their communities
- People prefer to have myrtle rust management over its absence.

Table 6. Generalised Mixed Logit model results

	Parameter mean estimates[1]		Standard deviation of random parameters	
Random parameters in utility function				
Prevent extinction of three species	0.301***	(0.13)	0.48***	(0.04)
Prevent extinction of six species	0.602***	(0.12)	0.30***	(0.13)
Prevent extinction of ten species	1.487***	(0.19)	1.12***	(0.15)
Reduce heritage impact to Low	1.102***	(0.17)	0.96***	(0.18)
Reduce heritage impact to Moderate	0.567***	(0.15)	0.45***	(0.04)
Reduce forest impact to Low	1.454***	(0.12)	0.28***	(0.05)
Reduce forest impact to Moderate	0.831***	(0.14)	1.10***	(0.31)
Reduce domestic impact to Low	0.891***	(0.10)	1.04***	(0.12)
Reduce domestic impact to Moderate	0.641***	(0.11)	0.83***	(0.13)
Reduce location spread to Low	0.284***	(0.10)	1.70***	(0.17)
Reduce location spread to Moderate	0.020**	(0.01)	0.64***	(0.11)
Nonrandom parameters in utility function				
Annual Tax Contribution	- 0.015***	(0.00)		
No Myrtle Rust Management Option	- 3.211***	(0.85)		
Current Funding is Low	0.83***	(0.30)		
Concerned about Personal Impact	3.41***	(0.87)		
Variance parameter in scale	4.83***	(0.37)		
Heterogeneity in scale factor				
Choice Task Difficulty	0.08***	(0.03)		
Choice Task Understanding	0.37***	(0.02)		
Model Fit Statistics				
Log Likelihood function	- 1,817			
Log Likelihood chi^2 stat (22 df.)	1,863***			
McFadden Pseudo R^2	0.36			
Number of observations	2,750			

***, **,* denote statistical significance at the 1%, 5% and 10% levels respectively for the null hypothesis that a parameter estimate is not significantly different from zero.
Standard errors in brackets.
[1] Parameter mean estimates indicates the estimated average value in the model, for each different parameter.

3.4 Monetary Value of Benefits

Applying model estimates (Table 6) and equation 1.10 (Appendix A4) generates estimates of respondents Willingness to Pay (WTP) for protection of myrtle rust susceptible biodiversity. WTP is an estimate of how much money a respondent would be willing to give up for a change in the relevant biodiversity quality outcome, and is calculated using the ratio of an attribute parameter and the cost parameter. Table 7 presents respondent annual WTP for reducing impacts on susceptible biodiversity from a baseline of severe levels of impact (Table 1). These estimates reveal that the highest marginal WTP is for preventing high extension levels, i.e., landscape- or ecosystem-level impacts, to a 'Low Level'.

Table 7. Willingness to pay for myrtle rust management outcomes

Myrtle rust management outcomes		Willingness-to-pay per person
Extinction of susceptible native species	Prevent **up to 3** susceptible native species becoming extinct	$21 (14,35)
	Prevent **up to 6** susceptible native species becoming extinct	$41 (32,51)
	Prevent **up to 10** susceptible native species becoming extinct	$101 (78,115)
Impacts on heritage and iconic urban and landscape trees	Restrict losses of susceptible heritage and iconic urban and landscape trees to **Moderate Level**	$38 (32,45)
	Restrict losses of susceptible heritage and iconic urban and landscape trees to **Low Level**	$74 (66,87)
Impacts on native forests	Restrict impacts on forests to **Moderate Level**	$61 (55,66)
	Restrict impacts on forests to **Low Level**	$98 (92,103)
Impacts on domestic orchards and ornamentals	Restrict impacts on domestic orchards and ornamentals to **Moderate Level**	$43 (31,52)
	Restrict impacts on domestic orchards and ornamentals to **Low Level**	$60 (48,73)
Location of myrtle rust infections	Restrict spread of disease to **Moderate Level**	$7 (-3,17)
	Restrict spread of disease to **Low Level**	$20 (-2,44)

$NZ 2017 Annual Per-Person Average (95% Confidence Interval)

3.4.1 Management Scenario Valuation

This section provides monetary estimates for management scenarios described by combinations of outcomes from Table 1. The six management scenarios described in Table 8 focus on prevention of species extinction, reduction of impact to heritage and urban iconic and landscape trees, and delaying the spread of the disease. Scenarios 1.1 to 1.3 assume that the initial virulence of the disease is severe, and that management can provide improvements to reduce impacts from that level. While scenarios 2.1 to 2.3 assume that disease virulence is lower at a moderate level.

Table 8. Myrtle rust management scenarios

Myrtle rust management scenarios		
Severe Virulence	1.1	• Prevent all extinctions out of possible 10 • Reduce impacts on heritage and iconic urban and landscape trees from severe to low
	1.2	• Prevent all extinctions out of possible 10 • Reduce impacts on heritage and iconic urban and landscape trees from severe to low • Delay spread by 2 years
	1.3	• Prevent all extinctions out of possible 10 • Reduce impacts on heritage and iconic urban and landscape trees from severe to low • Delay spread by 4 years
Moderate Virulence	2.1	• Prevent all extinctions out of possible 3 • Reduce impacts on heritage and iconic urban and landscape trees from moderate to low
	2.2	• Prevent all extinctions out of possible 3 • Reduce impacts on heritage and iconic urban and landscape trees from moderate to low • Delay spread by 2 years
	2.3	• Prevent all extinctions out of possible 3 • Reduce impacts on heritage and iconic urban and landscape trees from moderate to low • Delay spread by 4 years

Applying model estimates (Table 6) and equation 1.11 (Appendix A4) to the scenario outcomes (Table 8) generates Table 9. Individual willingness-to-pay estimates are calculated for the first year, and over a ten year horizon for three discount rates. Individual welfare values are aggregated up to the national level using New Zealand Census 2013 estimate of the number of individual tax payers with positive income (2,773,911). We multiply this by the proportion of myrtle rust management options chosen by respondents in choice tasks that impose a cost, out of the total number of choice options (79%). Figure 13 depicts the national aggregate values graphically.

Table 9. Valuation of myrtle rust management scenarios ($NZ 2017)

Myrtle rust management scenarios			10yr Present Value		
			Discount rate		
		First year value	2%	4%	8%
Per person average	1.1	175	1,603	1,476	1,268
	1.2	194	1,654	1,526	1,316
	1.3	194	1,702	1,570	1,355
	2.1	56	513	472	406
	2.2	68	537	496	429
	2.3	68	560	518	449
National aggregate (m)	1.1	384	3,513	3,234	2,779
	1.2	425	3,625	3,344	2,884
	1.3	425	3,730	3,440	2,969
	2.1	123	1,124	1,034	890
	2.2	149	1,177	1,087	940
	2.3	149	1,227	1,135	984

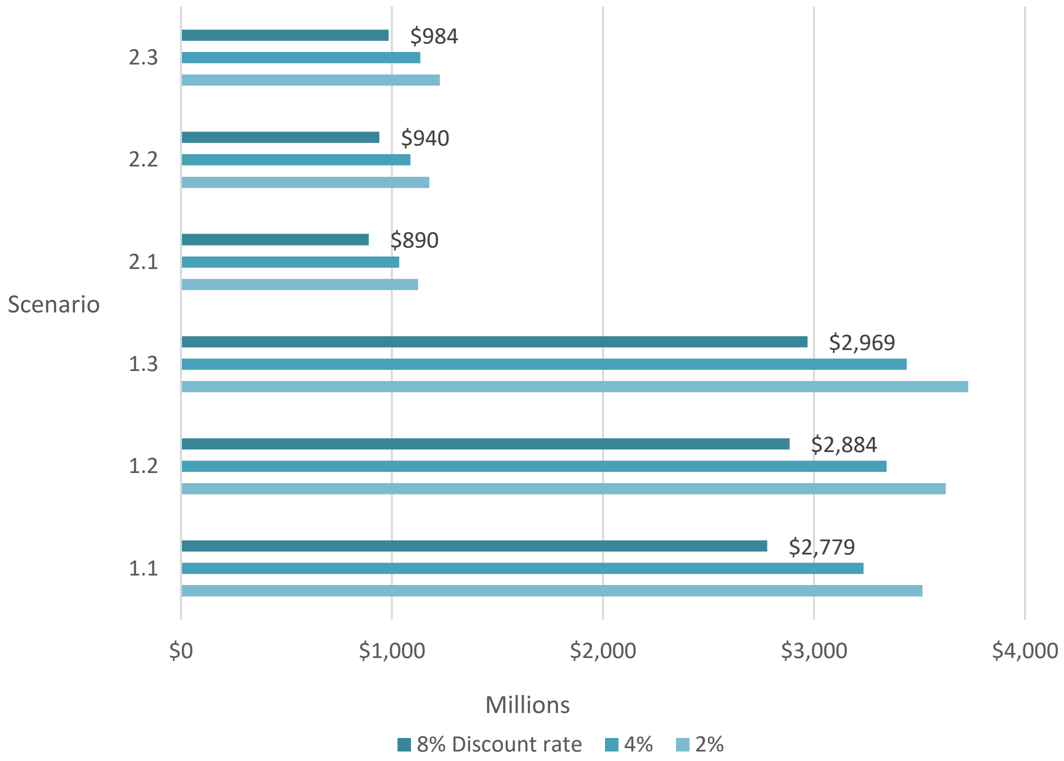

Figure 13 10yr present value of management scenarios

4 Conclusions

While the direct costs associated with myrtle rust control are observable in market transactions, many of the benefits do not have associated market signals with which to measure the value of protection to susceptible biodiversity. This report applied the economic non-market valuation approach of choice experiments, to estimate the value that New Zealand residents place on reductions in impacts to susceptible biodiversity from myrtle rust control and management. The WTP results found here are consistent with those of comparable choice experiment studies, finding significant public support for enhancement of biodiversity outcomes. The survey process achieved a sample of 550 respondents demographically representative of the NZ population.

The economic values estimated here indicate that at least some New Zealanders place a very high value on protecting susceptible biodiversity, heritage and landscape values from the effects of myrtle rust. It is important to note that value can be much higher than cost – the willingness to pay estimates are a measure of the maximum benefit accruing to individuals and therefore is the most they would pay, but they would prefer to pay much less if that were possible.

We acknowledge that the attributes we chose, and the way we characterised changes in them in response to control management are simplistic. We considered it impractical to fully depict the true level of complexity in our attribute descriptions and control outcomes, in the belief that would have made them far more difficult for respondents to comprehend and evaluate. It is therefore important to assess the extent to which myrtle rust management might deliver the simple biological outcomes we portrayed.

These limitations in part reflect the compressed time frame of this study, inherent in biosecurity response management. The work reported here was initiated and completed within a five week period.

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Appendix A: Statistical Method

This appendix provides technical details of statistical analysis of choice data. The appendix includes a brief description of the theoretical foundations of choice analysis followed by statistical probability estimation approaches, focusing on contemporary models applied in this report. Lastly, the method used in generating monetary estimates is described.

A.1 Conceptual Framework

In Choice Experiments (CEs), researchers are interested of what influences, on average, the survey respondents' decisions to choose one alternative over others. These influences are driven by people's preferences towards the attributes but also the individual circumstances such as their demographics or perceptions of the choice task (e.g., the level of difficulty or understanding) (Hensher et al. 2015).

Each alternative in a choice set is described by attributes that differ in their levels, both across the alternatives and across the choice sets. The levels can be measured either qualitatively (e.g., poor and good) or quantitatively (e.g., kilometres). This concept is based on the characteristics theory of value (Lancaster 1966) stating that these attributes, when combined, provide people a level of utility[7] *U* hence providing a starting point for measuring preferences in CE (Hanley et al. 2013; Hensher et al. 2015). The alternative chosen, by assumption, is the one that maximises people's utility[8] providing the behavioural rule underlying choice analysis:

$$U_j > U_i \qquad (1.1)$$

where the individual *n* chooses the alternative *j* if this provides higher utility than alternative *i*. A cornerstone of this framework is Random Utility Theory, dated back to early research on choice making (e.g., Thurstone 1927) and related probability estimation. This theory postulates that utility can be decomposed into systematic (explainable or observed) utility *V* and a stochastic (unobserved) utility ε (Hensher et al. 2015; Lancsar and Savage 2004).

$$U_{nj} = V_{nj} + \varepsilon_{nj} \qquad (1.2)$$

where *j* belongs to a set of J alternatives. The importance of this decomposition is the concept of utility only partly being observable to the researcher, and remaining unobserved sources of utility can be treated as random (Hensher et al. 2015). The observed component includes information of the attributes as a linear function of them

[7]Related terminology used in psychology discipline is *the level of satisfaction* (Hensher et al. 2015).
[8]In choice analysis, utility is considered as *ordinal utility* where the relative values of utility are measured (Hensher et al. 2015).

and their preference weights (coefficient estimates).

$$V_{nsj} = \sum_{k=1}^{K} \beta_k x_{nsjk} \quad (1.3)$$

with k attributes in vector x for a choice set s. Essentially, the estimated parameter β shows “the effect on utility of a change in the level of each attribute” (Hanley et al. 2013, p. 65). This change can be specified as linear across the attribute levels, or as non-linear using either dummy coding or effect coding approaches. The latter coding approach has a benefit of not confounding with an alternative specific constant (ASC) when included in the model (Hensher et al. 2015).

A.2 Statistical Modelling of Choice Probabilities

The statistical analysis aims to explain as much as possible of the observed utility using the data obtained from the CE and other relevant survey data. In order to do so, the behavioural rule (eq. 1.1) and the utility function (eq. 1.2) are combined (Hensher et al. 2015; Lancsar and Savage 2004) to estimate the probability of selecting an alternative j:

$$\Pr_{nsj} = \Pr\left(U_{nsj} > U_{nsi}\right) = \Pr\left(V_{nsj} + \varepsilon_{nsj} > V_{nsi} + \varepsilon_{nsi}\right) = \Pr\left(\varepsilon_{nsi} - \varepsilon_{nsj} < V_{nsj} - V_{nsi}\right) \forall j \neq i \quad (1.4)$$

where the probability of selecting alternative j states that differences in the random part of utility are smaller than differences in the observed part. A standard approach to estimate this probability is a conditional logit, or multinomial logit (MNL) model (McFadden 1974). This model can be derived from the above equations (1.2 and 1.3) by assuming that the unobserved component is independently and identically distributed (IID) following the Extreme Value type 1 distribution (see e.g. Hensher et al. 2015; Train, 2003). Although the MNL model provides a “workhorse” approach in CE, it includes a range of major limitations (see e.g. Fiebig et al. 2010; Greene and Hensher 2007; Hensher et al. 2015):

- Restrictive assumption of the IID error components
- Systematic, or homogenous, preferences allowing no heterogeneity across the sample
- Restrictive substitution patterns, namely the existence of independence of irrelevant alternatives property where introduction (or reduction) of a new alternative would not impact on the relativity of the other alternatives
- The fixed scale parameter obscures potential source of variation

Some or all of these assumptions are often not realised in collected data. These restrictive limitations can be relaxed in contemporary choice models. In particular, the random parameter logit (RPL) model (aka, the mixed logit model) has emerged in empirical application allowing preference estimates to vary across respondents (Fiebig, et al. 2010;

Hensher et al. 2015; Revelt and Train, 1998). This is done by specifying a known distribution of variation to be parameter means. The RPL model probability of choosing alternative *j* can be written as:

$$\Pr_{nsj} = \frac{\exp(\beta_n^{'} x_{nsj})}{\sum_J \exp(\beta_n^{'} x_{nsj})} \tag{1.5}$$

where, in the basic specification, $\beta_n = \beta + \eta_n$ with *η* being a specific variation around the mean for *k* attributes in vector *x* (Fiebig, et al. 2010; Hensher et al. 2015). Typical distributional assumptions for the random parameters include normal, triangular and lognormal distributions, amongst others. The normal distribution captures both positive and negative preferences (i.e., *utility* and *disutility*) (Revelt and Train, 1998). The lognormal function can be used in cases where the researcher wants to ensure the parameter has a certain sign (positive or negative), a disadvantage is the resultant long tail of estimate distributions (Hensher et al. 2015). The triangular distribution provides an alternative functional form, where the spread can be constrained (i.e., the mean parameter is free whereas spread is fixed equal to mean) to ensure behaviourally plausible signs in estimation (Hensher et al. 2015). Further specifications used in modelling include parameters associated with individual specific characteristics (e.g, income) that can influence the heterogeneity around the mean, or allowing correlation across the random parameters. The heterogeneity in mean, for example, captures whether individual specific characteristics influence the location of an observation on the random distribution (Hensher et al. 2015). In this study, the frequency of visits to rivers, streams and lakes was used to explain such variance.

Another way to write this probability function (in eq. 1.4) (Hensher et al. 2015) involves an integral of the estimated likelihood over the population:

$$L_{njs} = \int_{\beta} \Pr_{nsj}(\beta) f(\beta|\theta) d\beta \tag{1.6}$$

In this specification, the parameter θ is now the probability density function conditional to the distributional assumption of β. As this integral has no closed form solution, the approximation of the probabilities requires a simulation process (Hensher et al. 2015; Train, 2003). In this process for data *X*, *R* number of draws are taken from the random distributions (i.e. the assumption made by the researcher) followed by averaging probabilities from these draws; furthermore these simulated draws are used to compute the expected likelihood functions:

$$L_{nsj} = E(\Pr_{nsj}) \approx \frac{1}{R} \sum_R f(\beta^{(r)} | X) \tag{1.7}$$

where the $E(\Pr_{nsj})$ is maximised through Maximum Likelihood Estimation. This specification (in eq. 1.6) can be found in Hensher et al. (2015). In practice, a popular simulation method is the Halton sequence which is considered a systematic method to draw parameters from distributions compared to for example, pseudo-random type approaches (Hensher et al. 2015).

A.3 Econometric Extensions

Common variations of the RPL model include specification of an additional error component (EC) in the unobserved part of the model. This EC extension captures the unobserved variance that is alternative-specific (Greene and Hensher 2007) hence relating to substitution patterns between the alternatives (Hensher et al. 2015). Empirically, one way to explain significant EC in a model is SQ-bias depicted in the stochastic part of utility if the EC is defined to capture correlation between the non-SQ alternatives (Scarpa et al., 2005).

Another extension which has gained increasing attention in recent CE literature, is the Generalized Mixed Logit (GMXL) model (Czajkowski et al. 2014; Hensher et al. 2015; Juutinen et al. 2012; Kragt 2013; Phillips 2014). This model aims to capture remaining unobserved components in utility as a source of choice variability by allowing estimation of the scale heterogeneity alongside the preference heterogeneity (Fiebig et al. 2010; Hensher et al. 2015). This scale parameter is (inversely) related to the error variance, and in convenient applications such as MNL or RPL, this is normalised to one to allow identification (Fiebig et al. 2010; Louviere and Eagle 2006). However, it is possible that the level of error variance differs between or within individuals, due to reasons such as behavioural outcomes, individual characteristics or contextual factors (Louviere and Eagle 2006).

Recent GMXL application builds on model specifications presented in Fiebig et al. (2010), stating that β_n (in eq. 1.4) becomes:

$$\beta_n = \sigma_n \beta + \gamma \eta_n + (1-\gamma)\sigma_n \eta_n \tag{1.8}$$

where σ is the scale factor (typically = 1) and $\gamma \in \{0,1\}$ is a weighting parameter indicating variance in the residual component. In the case the scale factor equals 1, this reduces to the RPL model. The importance of the weighting parameter is the impact on the scaling effect on the overall utility function (population means) versus the individual preference weights (individual means): when γ parameter approaches zero the scale heterogeneity affects both means, whereas when this approaches one the scale heterogeneity affects only the population means (Hensher et al. 2015; Juutinen et al. 2015). Interpretation of these parameters includes

- If γ is close to zero, and statistically significant, this supports the model specification with the variance of residual taste heterogeneity increases with scale (Juutinen et al. 2012); and

- If γ is not statistically significant from one, this suggests that the unobserved residual taste heterogeneity is independent of the scale effect, that is the individual-level parameter estimates differ in means but not variances around the mean (Kragt, 2013)

The scale factor specification (eq. 1.7) can also be extended to respondent specific characteristics associated with the unobserved scale heterogeneity (Hensher et al. 2015; Juutinen et al. 2015):

$$\sigma_n = \exp\{\overline{\sigma} + \tau\omega_n\} \tag{1.9}$$

where $\overline{\sigma}$ *is* the mean parameter in the error variance; and ω is unobserved scale heterogeneity (normally distributed) captured with coefficient τ (Hensher et al. 2015; Juutinen et al. 2015; Kragt, 2013). Juutinen et al. (2012), for example, in context of natural park management found that respondents' education level and the time spent in the park explained the scale heterogeneity ($\tau > 0$, p-value < 0.01). In this study, the respondents indicated levels of choice task understanding and difficulty were used to explain scale heterogeneity.

A.4 Estimation of Monetary Values

Typically the final step of interest in the CE application is the estimation of monetary values of respondent preferences for the attributes considered in utility functions. These are commonly referred to as marginal willingness-to-pay (WTP). WTP estimation is based on the marginal rate of substitution expressed in dollar terms providing a trade-off between some attribute k and the cost involved (Hensher et al. 2015) and is calculated using the ratio of an attribute parameter and the cost parameter. WTP can take into account interaction effects, if statistically significant, such as with the respondent demographics. WTP of attribute *j* by respondent *i* is calculated as the ratio of the estimated model parameters accommodating the influence of the random component (Cicia et al. 2013) as:

$$WTP_i^j = -\left(\frac{\beta_j + \varepsilon_{ij}}{\beta_{price} + \varepsilon_{ip}}\right) \tag{1.10}$$

The estimated mode parameters can also be used to estimate compensating surplus (CS) as a result of policy or quality change in a combination of attributes, using (Hanemann, 1984):

$$\mathbf{CS} = \frac{-1}{\beta cost}\left[\ln\sum_{j=1}^{J}\exp\left\{V_j^0\right\} - \ln\sum_{j=1}^{J}\exp\left\{V_j^1\right\}\right] \tag{1.11}$$

which calculates the difference in utilities before the policy or quality change (V_0) and after the policy or quality change (V_1) (Hanley et al. 2013; Lancsar and Savage 2004). Similar to WTP, the monetary estimation of this change is possible by using the estimate for the monetary attribute $\beta_{cost.}$. Lastly, there are some challenges associated with the empirical estimation of the WTP in the RPL based models. One approach is to use a fixed cost, which simplifies the WTP estimation (Daly et al. 2012) but which may not be as behaviourally a plausible consideration as allowing heterogeneous preferences towards the cost attribute (Bliemer and Rose, 2013; Daziano and Achtnicht, 2014). Conceptually, the estimated cost parameter is a proxy for the marginal utility of income for respondents and economic theory suggests individuals will respondent differently to varying income levels. The use of a random cost parameter however, presents complications in deriving population distribution moments from the ratio of two random parameters.

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