CEBRA Report Cover Page

Title, ID, & Output #	*Biosecurity Response Decision Support Framework, CEBRA 170820, Deliverable 3, Draft Final Report*		
Project Type	*Standard*		
MPI Project Sponsor	*Sam Leske (at inception Veronica Herrera, followed by Geoff Gwyn)*	**MPI Project Leader/s**	*Davie Hutchinson (at inception Mike Taylor)*
CEBRA Project Leader	*Susie Hester*	**DAWR Collaborator**	*NA*
External Collaborators	*A/P Peter Tait, Lincoln University (Non-market valuation); Dr Omphile Temoso, University of New England (Data analysis)*		
Project Objectives	The overarching purpose of this two-year project is to improve and strengthen MPI's decision making around new pest or disease incursions that may pose a risk to the economic, environmental, human health and socio-cultural values of New Zealand. Its original objectives were threefold: 1. To review MPI's current decision-making framework and process for responding to new pest and disease incursions across all sectors of the New Zealand economy, environment and community. 2. Review MPI's investment into new pest and disease incursions over the last 5 years across the entire biosecurity response portfolio. 3. Recommend ways in which the decision-making framework may be improved and updated. During the course of the project, MPI undertook its own internal review of decision-making in the response context. As a result, the project team decided that objective 1 would no longer be considered by the project.		
Outputs	The two main outputs of this project are a set of guidelines for undertaking non-market valuation (Tait and Rutherford, 2018) and an excel-based 'benefit transfer template' for use by response staff in undertaking 'screening' NMV (developed by A/P Peter Tait).		

CEBRA Workplan Budget	**Year 2015-16**	**Year 2016-17**	**Year 2017-18**	**Year 2018-19**
		25,000	*68,000*	

Project Changes	During the course of the project, MPI undertook its own internal review of decision-making in the response context. As a result the project team decided that objective 1 would no longer be considered by the project.
Research Outcomes	The ability to undertake in-house NMV to understand the magnitude of non-market impacts; improvement to CBA methods.
Recommendations	1. That benefit transfer be undertaken during the response phase of an incursion to screen the magnitude of potential environmental impacts. 2. That pre-emptive primary studies be undertaken on the non-market values of pest incursions, particular in the marine environment. 3. That step-by step guidelines for undertaking CBA during the initial response phase be included in *Biosecurity Response: Cost Benefit Analysis* 4. That data be collected in a way that would allow for detailed analysis of response expenditure over time 5. That consideration should be given to hiring an economist who specialises in non-market valuation and embedding that individual within the response team.
Related Documents	Tait, P and Rutherford, P (2018) *Non-market valuation of environmental impacts for biosecurity incursion Cost Benefit Analysis: A guidance manual for public policy*, Agribusiness and Economics Research Unit, Lincoln University
Report Complete	Final Report has undergone SAC review

CEBRA Project 170820: Biosecurity response decision support framework

Final Report

Susie Hester[1,2],

Peter Tait[3] and Paul Rutherford[3]: Non-Market Valuation (Appendix B)

Omphile Temoso[4]: Data Analysis (Appendix C)

1. CEBRA, The University of Melbourne
2. UNE Business School, University of New England
3. Agribusiness and Economics Research Unit, Lincoln University
4. UNE Business School, University of New England

September 5 2019

Acknowledgements

This report is a product of the Centre of Excellence for Biosecurity Risk Analysis (CEBRA). In preparing this report, the authors acknowledge the financial and other forms of support provided by the NZ Ministry for Primary Industries, the Department of Agriculture and Water Resources and the University of Melbourne.

The authors are grateful to the following people who generously gave their time to attend at least one of the three project workshops: Claudia Recker, Fiona Roberts, Sally Lees, Veronica Herrera, Christine Reed, Andre van Halderen, Frances Velvin, George Gill, Daniel Klusa, Ivan Luketina, Blake Dearsley, Melanie Russell, James Kilbride, Amelia Pascoe, Erik Van Eyndhoven (Ministry for Primary Industries); Chris Green, Verity Forbes (Department of Conservation); Chris Housten (Beef & Lamb NZ); Dave Hodges (Dairy NZ); Richard Palmer (Hort NZ); Sherree Judan, Stuart Wood, Daniel Kluza, James Kilbride, Puneet Chugh (MPI), Rod Hitchmough (DOC), John Rolfe (Central Queensland University), Brian Bell (Nimmo Bell), David Hutchison, Mike Taylor, Kathy Walls, Grant Boston, Christine Reed, Stephen Bell, John Appleby, Mike Harre (MPI); Darran Austin (MPI/MFE); Peter Tait (Lincoln University).

The authors also thank Erik Van Eyndhoven and Kathy Walls for their development of case studies using the benefit-transfer tool produced during this project; and David Hutchison and Kathy Walls for their review of this document.

Table of Contents

1 Executive Summary

The overarching purpose of this two-year project is to improve and strengthen MPI's decision making in response to new pest or disease incursions that may pose a risk to the economic, environmental, human health and socio-cultural values of New Zealand.

Activities during year one of the project identified non-market valuation (NMV) – valuing the impacts of incursions on environmental goods and services – as a key focus for year two of the project. NMV becomes important in cost-benefit analysis (CBA) of response options when pests and diseases have non-market impacts. Typically these impacts are more challenging to value than market impacts. When non-market impacts are not included, the resulting CBA will be incomplete and may lead to inefficient resource allocation. This issue is seen as particularly important in the context of negotiating Government Industry Agreements.

The economics discipline provides a range of rigorous and credible methods for valuing the non-market impacts of pest and incursions. Unfortunately, MPI staff with these skills are not always available to assist in developing the CBA and business cases for a response. This report recommends ways to improve the capacity of decision makers to incorporate NMV into decisions undertaken in the response context, including the use of a 'benefit-transfer tool' that would allow staff to rapidly understand the magnitude of non-market impacts.

1.1 Recommendations

1. When a CBA is developed during the response phase of an incursion, benefit transfer should be undertaken to screen the magnitude of potential environmental impacts.

The Excel-based 'benefit-transfer tool' developed in this project should be used to indicate the nature and scale of non-market impacts. This analysis may be done in-house, reasonably quickly, and only requires that similar, primary studies have already been undertaken. Results from using the tool would also indicate whether further investment in a larger primary NMV study is required.

2. That pre-emptive primary studies be undertaken on the non-market values of pest and disease incursions.

The economics discipline provides a range of rigorous and credible methods for valuing the non-market impacts of pest and disease incursions. Unfortunately, most of these methods involve primary data collection through surveys, and may take upward of six weeks and require significant resources to implement. The methods are therefore usually inappropriate for application in the time-critical response context of invasive species. Primary non-market valuation studies, undertaken 'pre-emptively', could provide a pool of data from which to make inferences about likely impacts of -pest/disease incursions once an incursion is notified. Investment in such studies should be viewed as an investment in response preparedness, which will potentially result in improved response management in the future.

3. That step-by step guidelines for undertaking CBA during the initial response phase be included in *Biosecurity Response: Cost Benefit Analysis*

When staff who are not economists (or where assistance from economists is not available) are required to undertake CBA they will benefit from detailed guidelines or templates from which to develop a CBA. This will allow CBAs to be consistent and rigorous. A standard approach for undertaking a CBA should be adopted for these situations – a nine-step approach to CBA, developed by CEBRA, would provide a useful improvement to the current process. This incorporates NMV at step 5, thus embedding NMV in CBA.

4. That data be collected in a way that would allow for detailed analysis of response expenditure over time

In order for a meaningful analysis of response spending over time to occur, data on pest spread and expenditure on management inputs would need to be stored in a way that is easily and readily accessible by the analyst. This data should also be reported in time steps of less than one year, and **all** costs of response expenditure would need to be recorded, including the cost of all MPI staff time.

5. That serious consideration be given to hiring an economist who specialises in NMV and embedding that individual within the response team.

The skills of an applied economist who specialises in non-market valuation would be an asset to the current response team. It would be beneficial for the economist to be embedded in the team and be dedicated to assisting with the development of CBAs – particularly the NMV aspects –, assisting in negotiation of tailored NMV with third-party contractors, and undertaking analysis of response data in order to understand changes in patterns of expenditure over time.

2 Introduction

New Zealand's Ministry for Primary Industries (MPI) has a framework (viz. Biosecurity Response Knowledge Base) and process for guiding decision making in response to new pest or disease incursions that may pose a risk to the economic, environmental, human health and socio-cultural values of New Zealand, regardless of the affected sector or size of the sector. Decision-makers use this process and prioritisation tool in combination with information from risk assessment templates, cost-benefit analysis (CBA), mapping capabilities, and associated documentation, to support the decision analysis and conclusions about which response option to pursue.

A review of decision-making in the response context was requested in order to strengthen MPI's response decision making across various sectors. Outputs from the review could also be applied to help guide and justify cost sharing with industry under Government Industry Agreement (GIA) arrangements.

2.1 Objectives

The overarching purpose of this project is to improve and strengthen MPI's decision making on responding to new pest or disease incursions that may pose a risk to the economic, environmental, human health and socio-cultural values of New Zealand. Its objectives are two-fold:

1. Review MPI's investment into new pest and disease incursions over the last 5 years across the entire biosecurity response portfolio.
2. Recommend ways in which the decision-making framework may be improved and updated.

2.2 Methodology

In order to understand current practices in the time-critical response context, and recommend improvements, the review team:

i) Consulted with MPI staff;
ii) Undertook data analysis; and
iii) reviewed relevant scientific literature, reports and MPI policies and procedures

2.2.1 Staff consultation

Staff consultation occurred during three project workshops and through semi-structured discussions with MPI staff involved in biosecurity responses. Staff participating in the workshops came from both MPI and the Department of Conservation (DOC) and were from a range of discipline backgrounds. Most had significant experience in designing, implementing and administering responses to a wide range of pests and diseases.

Unstructured discussions between the lead author and staff occurred during July and November 2016. Staff talked openly of their own experiences with responses, particularly where problems typically occurred. Key themes that emerged from discussions with staff were:

- the absence of a flexible and user-friendly cost-benefit analysis (CBA) tool for use in rapid-response decision making;
- lack of expertise in the incorporation of non-market valuation in CBA which results in an inability to adequately and appropriately understand and value the impact of pests and diseases on environmental, social and/or cultural values
- vague language in the Response Prioritisation Tool (and other tools);
- lack of rigour and transparency in the use of experts and Technical Advisory Groups (TAGs);
- the need to improve the consistency, timeliness, flexibility and robustness of response decisions; and
- capturing political and reputational risk in the decision-making process

The first project workshop, held in November 2016, focussed on characteristics of ‘successful’ responses. A key outcome of the workshop was a list of attributes, or criteria, that a successful response might typically contain. Case-study examples of actual responses that did and did not meet these criteria were suggested for further analysis.

A second workshop, held in 2018, focussed on non-market valuation (NMV) and its practical application in the response context, in response to staff concerns about this aspect of decision-making. Staff were involved in further discussions of non-market valuation and in the development of an Excel-based ‘benefit-transfer tool’. Staff envisaged that this tool would be used to estimate the magnitude of non-market impacts, a key input into their cost-benefit analyses of managing pest and disease incursions. NMV is discussed in Chapter 4 and Appendix B.

2.2.2 Data Analysis

It was originally envisaged that data from 50 incursion responses implemented by NZMPI 2004-05 to 2015-16 would be analysed to understand the following:

1. patterns in expenditure overtime by: pest type, sector affected, type of impact;
2. whether the characteristics of ‘successful’ eradications as discussed in Workshop 1 were borne out by the data;
3. whether NZMPI is getting ‘better’ at responding, e.g in terms of time taken to meet particular response activities.

The data analysis is reported in more detail in Chapter 5 and Appendix C. Unfortunately data was recorded in annual time steps, which meant too few data points (2-3) were available on each variable to allow for a meaningful analysis. A decision was made to reduce the scope of the analysis.

2.2.3 Literature review

A review of relevant scientific literature, reports and MPI policies and procedures was used to develop a set of resources that could assist staff with development of CBAs for responses to new incursions.

3 Cost-benefit analysis

Cost-benefit analysis (CBA) is the standard and well-accepted method of evaluating the cost effectiveness of response options in the management of pest and disease incursions. Benefit-cost analysis can be thought of as an equation with response costs on one side and the losses that will be avoided if the incursion is not managed, which would therefore be the benefits, on the other. If the response costs are estimated to be less than the avoided losses then carrying out the response is economically the better option. The method consists of identifying and estimating the costs of carrying out the response plan and the costs forecast to be incurred from the impacts of the incursion if it were left unmanaged - the ‘do nothing’ counterfactual. These two sets of costs are then compared in terms of net present value (NPV) and the alternative with the highest NPV is selected. It is important to characterise the counterfactual accurately because the costs of management actions will be measured against it.

Since impacts of a particular pest will mostly accrue over time, a key part of a BCA is predicting the extent of each impact and the future time periods in which they are likely to occur. This may mean taking account of social, political and climatic uncertainty that could affect impacts in the future. A crucial element of estimating impact will therefore be predicting the spread of the pest. This is made more difficult in the time-critical response context because key information on spread and impact of the pest or disease may be difficult to collate or may not exist, and it is challenging to value the non-market impacts of an incursion. In this situation it can be tempting to make decisions based on only the easily measurable impacts. When this is the case, environmental resources may be implicitly undervalued and the resulting CBA will be incomplete and may lead to inefficient resource allocation. It may even be the case that a response is not mounted when it would have occurred if non-market impacts had been included. A range of tools for non-market valuation (NMV) is available. These are discussed in Chapter 4 and Appendix B.

Table 1. Major steps in undertaking a benefit-cost analysis. (Modified from: OBPR 2016)

Step	Actions
1	Specify the option(s).
2	Determine the costs of the response action (e.g. labour, materials, chemicals)
3	Identify impacts (and levels of uncertainty).
4	Predict the impacts over time (the type/s of environmental, social and/or economic harm caused, and levels of uncertainty) if spread remains unmanaged
5	Attach dollar values to impacts (these are the benefits from management).
6	Discount and compare costs and benefits of alternatives.
7	Calculate the costs and benefits using net present value.
8	Perform sensitivity analysis.
9	Assess the BCA and reach a conclusion.

A CBA thus provides a way to incorporate market and non-market impacts, and to organise information about a proposed change in a systematic, objective and transparent manner. At the time of writing, there were no standard spreadsheets or detailed step-by-step guidance provided for MPI staff in completing *Biosecurity Response: Cost Benefit Analysis*. It is recommended that the nine-step approach to CBA, detailed in Summerson et al. (2018) and summarised in Table 1, be incorporated into relevant response documents.

3.1 Resources for CBA

A large range of existing resources provide guidance on undertaking CBAs, with some specifically dealing with CBAs in pest and disease responses. Resources range from written guidelines to spreadsheet-based tools. A recommended list of useful resources to assist staff with CBA is as follows:

Generic guidance

- The Treasury (2015) *Guide to Social Cost Benefit Analysis*, NZ Government, 78pp. Available at https://treasury.govt.nz/publications/guide/guide-social-cost-benefit-analysis
- Office of Best Practice Regulation (2016) *Cost-Benefit Analysis Guidance Note*. Department of Prime Minister and Cabinet, Canberra. Available at https://www.pmc.gov.au/resource-centre/regulation/cost-benefit-analysis-guidance-note

Guidance in a biosecurity context, including NMV techniques

- Summerson, R., Graham, S. and Hester, S. (2018) *Methodology to guide responses to marine pest incursions under the National Environmental Biosecurity Response Agreement*, Final Report CEBRA 1608E, Centre of Excellence for Biosecurity Risk Analysis, University of Melbourne, 65pp. Available at https://cebra.unimelb.edu.au/research/data-and-information/response-to-a-marine-pest-incursion
- Emerton, L. and Howard, G. (2008) *A Toolkit for the Economic Analysis of Invasive Species*. Global Invasive Species Programme, Nairobi. Available at http://especes-envahissantes-outremer.fr/wp-content/uploads/2017/03/toolkit_economic_analysis.pdf

Tools

- AgResearch (2017) Cost Benefit Analysis for Regional Weed Management. Available at https://www.agresearch.co.nz/cba/cba.php

  This web-based tool enables a CBA to be conducted for a Weed Management Programme proposed for inclusion in a Regional Management Plan as required by the New Zealand Biosecurity Act 1993.
- Benefit-transfer tool developed by Peter Tait (see Section 4.1 within this report)

4 Non-market valuation in CBA

Ideally, CBA of response options would include environmental, socio-cultural, and human health impacts in addition economic impacts. Where this does not occur, environmental, cultural and human resources may be implicitly undervalued and the resulting CBA will be incomplete and may lead to inefficient resource allocation. Valuing the impacts of a pest or disease on the environment, society and culture is likely to require non-market valuation (NMV) – a set of techniques used to calculate value when market prices are unavailable.

Staff consultation identified non-market valuation (NMV) in general, and of the environment in particular, as a key problem for decision-making in the response context. While staff were aware that CBAs of response options should include environmental impacts (where these occur), there was a lack of understanding of available methods, and the contexts in which they could be applied. In addition, there was a perception that NMV studies would always need to be outsourced, and the time and resources required were rarely available. The ability to value environmental impacts appropriately is viewed as particularly important in the context of negotiating Government Industry Agreements.

The project team worked with MPI staff during several workshops and meetings to explore NMV techniques, the context in which they would be applied, the skills required to implement each, and typical timeframe required for implementation (Figure 1). Figure 1 summaries the main considerations for biosecurity response staff when deciding how to progress a NMV exercise. For a basic analysis – ie. for the purposes of screening relative magnitudes of values – a basic benefit transfer (see 4.3) or contingent valuation could be carried out in house, at relatively low cost, in a short time frame. These two techniques would not require a high level of expertise in CBA

Figure 1. Valuation method scored against method robustness, required CBA experience, cost and weeks to complete (Source: Tait and Rutherford 2018).

or NMV. The trade-off is that method robustness is relatively low. If these initial assessments reveal the need for fuller, more robust estimates, then the expertise of a specialist NMV economist would be sought. Such a practitioner would be requested to perform a tailored choice experiment or contingent valuation.

The end result of staff consultation on NMV was: i) the development of a set of guidelines for NMV (Tait and Rutherford 2018); and ii) an Excel-based 'benefit-transfer tool'. The guidelines appear as Appendix B and the benefit transfer tool is discussed below, following a brief discussion of environmental goods and services and their valuation.

4.1 Identifying and valuing environmental goods and services

The Total Economic Value (TEV) framework (Pearce, 1993; Barbier et al. 1997; Pascual 2010), is a useful way to understand the range of environmental goods and services that might be affected by an invasive species, and how to value the impact (Figure 2). Once the different impacts have been categorised according to the TEV framework the next step is to choose the appropriate technique for calculating values for those impacts. The following discussion is drawn from Summerson et al. (2018).

Under the TEV framework the value of environmental goods and services is the sum of the environment's use and non-use values. Use values are associated with aspects of the environment that are directly useful for production and consumption activities, such as extraction of raw materials or physical products; and non-use values are associated with experiences that occur in the valuer's mind.

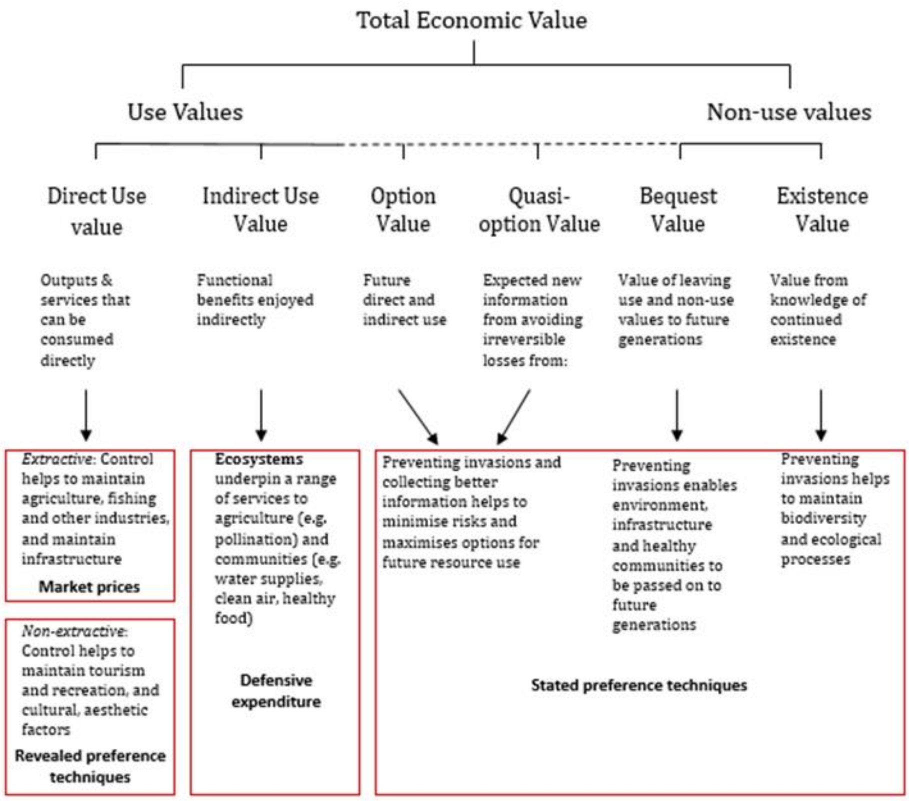

Figure 2. Total Economic Value. (Modified with permission from a presentation by John Rolfe.)

Use values may be further classified into

- *direct use values* – these result from the direct human use of the environment. Examples are 'consumptive' use activities such as fishing; and 'non-consumptive activities' such as using the environment for recreation activities or tourism. Since these consumptive activities are linked to the economic system, market values should be used to evaluate the damage that a pest-incursion would have incurred if left unmanaged. For non-consumptive activities, revealed preference techniques should be used (see Summerson et al. 2018 for more details).
- *indirect use values* – these are the values that people hold for the regulation services provided by species and ecosystems. Specific examples include pest control, carbon sequestration, water purification and soil fertility. This use of the environment is indirectly linked to the economic system, so while it is possible to derive a market value, it is a more difficult process. The defensive expenditure approach should be used to evaluate indirect use values of the environment (see Summerson et al. 2018 for more details).

Non-use values of the environment, for example, the existence of a pristine beach, are not linked to economic production or consumption, but because they influence human well-being, they need to be considered when the environment is valued. Non-use values may be further categorised as:

- *altruism/bequest value* – this is the value that an individual attaches to the fact that others (whether in this generation or future generations) will be able to benefit from the environment.
- *existence value* – this is satisfaction gained by the knowledge that an environmental asset exists.

Stated preference techniques should be used to evaluate these non-use values.

Impacts are relatively easy to value when market prices are available – the market price is an estimate of an individual's willingness to pay for an additional unit of a good or service (or to avoid a cost). When summed over all people this becomes the community's willingness to pay to obtain a benefit or avoid a cost. When there is no market for a particular good or service, as is often the case for environmental goods and services, it becomes necessary to estimate the willingness to pay for these non-market goods indirectly. Two broad groups of 'non-market valuation' methods have been developed for this purpose: i) those that use revealed preference techniques; and ii) those that use stated preference techniques.

Revealed preference techniques seek to elicit peoples' willingness to pay for a good or service by observing their actual behaviour in real, related markets, while stated preference techniques involve directly surveying people's hypothetical behaviour in carefully constructed markets for the environmental good/service in question. More information on revealed preference techniques is available in Summerson et al. (2018).

4.1.1 Stated preference techniques

Stated preference techniques are used to value non-use aspects of the environment – values that individuals attach to the fact that others will be able to benefit from the environment (altruism/bequest value), or the satisfaction that an environmental asset actually exists (existence value). The two main stated preference techniques are *choice modelling* and the *contingent valuation*.

Contingent valuation

Using contingent valuation (CV), people are asked directly about their willingness to pay (WTP) for improvements in particular environmental goods and services. To understand WTP, people are asked (once) in a survey, to compare a business-as-usual scenario (no extra cost) with an improvement scenario (extra payment). To elicit accurate answers, a CV survey must first establish the nature of the good to be provided, and the way in which payment would hypothetically be made, for example in user fees, higher local taxes, contributions to a non-profit environmental fund etc (Commonwealth of Australia, 2016).

Choice modelling

In choice modelling studies, respondents are presented with a number of alternatives and asked to choose between them. As was the case with CV, choice modelling presents a business-as-usual option, and improvement options at an extra cost. CM differs from CV in that it describes the situation of interest in terms of attributes; it varies improvement options over different levels; and respondents are asked to complete a series of trade-offs (Rolfe and Windle, 2015). As a result, CM generates much richer information than CV.

4.2 Benefit transfer

In the initial phases of responding to a pest or diseases incursion it is usually not possible to spend time on primary studies required in many of the valuation methods mentioned above. Instead, analysts are sometimes able to use findings from similar studies to calculate values of avoided impacts, through a process known as benefit transfer. Benefit transfer involves transferring existing estimates of non-market values from a study site to the target/policy site, where the sites are considered broadly similar. Values from the study site may be adjusted for differences in income, prices and demographic variables (See Appendix B). Studies that might be appropriate to use in benefit transfer may be located on EVRI (Environmental Valuation Reference Inventory), a searchable database containing a large number of non-market valuation studies from across the globe.

In order that appropriate data is available to undertake benefit transfers in the future, primary non-market valuation studies, undertaken ‘pre-emptively’, could provide a pool of data from which to make inferences about likely impacts of marine-pest incursions once an incursion is notified.

4.2.1 Benefit transfer tool

Benefit transfer refers to a set of methods for applying previously estimated *willingness to pay* values from a ‘study site’ to a ‘policy site’ of interest – the area, social context, and environment affected by the incursion where no values are currently available. Because conducting primary valuation studies can be time consuming and resource intensive, investigating the possibility of using a benefits transfer approach is worthwhile, especially where the purpose is to screen relative magnitudes of values.

Source (primary) studies may be found at the Environmental Valuation Reference Inventory (EVRI) in Canada (http://www.evri.ca/) to which the New Zealand Ministry for the Environment is a funder. The main caveat to using benefit transfer is that, given the current limited availability of suitable source studies, estimates of environmental values are unlikely to achieve equivalence with conducting a primary valuation study.

The benefit transfer template developed in this project should be used in conjunction with Chapters 4 and 5 of Tait and Rutherford (2018). The template contains four worksheets:

1. 'How to': details the steps involved in undertaking the benefit transfer;
2. 'Dashboard': where users insert information from the primary study of interest, as well as information on which regions of NZ it will be applied to;
3. 'Report': gives transfer values in terms of willingness to pay per person
4. 'Reporting guidance': lists important assumptions that sit behind the template

Use of the tool is now illustrated using two examples.

4.2.2 Example 1: *Epilobium hirsutum* (great willow herb) [1]

Problem:

In May 2018 the invasive weed *Epilobium hirsutum* (great willow herb) was found growing in several areas of Canterbury. E. *hirsutum* had not previously been recorded as present in New Zealand. Great willowherb is a weed of wetlands where it can form dense stands, impeding water flow. It may crowd out native wetland plants and spread to undisturbed damp areas, invading existing vegetation.

An estimate of the extent of the damages was required for a preliminary CBA and to inform whether resources should be allocated to a more robust NMV.

Primary study

A search of the literature for suitable source studies was conducted, with the following study found to be suitable for transfer between the source study and policy application[2]:

> Bell, B.A, Yap, M. and Cudby, C. (2011). *Biodiversity Valuation Manual: A technical manual for MAF BNZ (Revised)*. Nimmo-Bell & Company Ltd, New Zealand[3].

The study used a choice modelling approach to investigate the willingness to pay for maintaining or limiting deterioration of key environmental aspects of a typical New Zealand Lake, due to a hypothetical invasion of the weed hydrilla (*Hydrilla*

---

[1] This case study was undertaken by Erik Van Eyndhoven, MPI.

[2] It is important to consider the biophysical, population, scale of change and framing factors of the primary study compared to the policy site. See Tait and Rutherford (2018), Chapter 4, for details of this process.

[3] Additional results from this study are in Bell B. A., Yap M., & Cudby C. (2009) *Valuing Indigenous Biodiversity in the Freshwater Environment*, In: Annual NZARES Conference. NZARES, Nelson, New Zealand.

verticillata). The payment vehicle for eliciting willingness to pay is a special tax on ratepayers, assessed annually for five years.

Hydrilla is a submerged, perennial, aquatic plant and known as one of the world's worst aquatic weeds. It is able to growth prolifically in a wide range of ecological conditions, forms mono-specific stands that can degrade fish and wildlife habitat, and displaces it displaces native vegetation (Hofstra and Champion, 2006). Weed beds of hydrilla are also a direct nuisance to lake users, and plant material that has washed ashore, putrefies on beaches reducing the aesthetic value of the lakes, and access to the water. Hydrilla is currently restricted to three lakes in the Hawkes Bay area of New Zealand.

Lake Rotoroa (otherwise known as Hamilton Lake) was chosen as the freshwater system under threat because it has a high risk of hydrilla invasion, has a long history of management, has a high profile due to shoreline housing and recreational use and has some indigenous biodiversity similar to other NZ lakes (Bell et al. 2009).

Application

Bell et al. (2011) investigated the willingness to pay to avoid the impacts of *hydrilla* on a lake in the Waikato Region. Their analysis suggested that households were willing to pay NZD244 per annum over five years to avoid *hydrilla* establishing in the lake. This was higher than what they were willing to pay to mitigate *hydrilla's* impacts if it were to establish in the lake.

Basic Unit Value Transfer Report

Source Study

Source Study:	**Bell, Yap and Cudby (2011).**
Study WTP:	**$244 per household (HH)**
Study Year:	**2009**
Study Location:	**Waikato Region**

Notes

0

Transfer Value Adjustments

Region of Benefits	**New Zealand**
Time span of bene	**5 years**
Discount rate:	**8%**
Scale:	**Same**
Substitutes:	**Same**

Transfer Values

Adjusted annual WTP/HH:	**$ 291.86**		
Total Present Value/HH:	**$ 1,186.93**		
% of Beneficiaries WTP:	50%	75%	100%
Total Aggregate Beneficiaries WTP:	$ 919,658,145	$ 1,379,487,217	$ 1,839,316,290

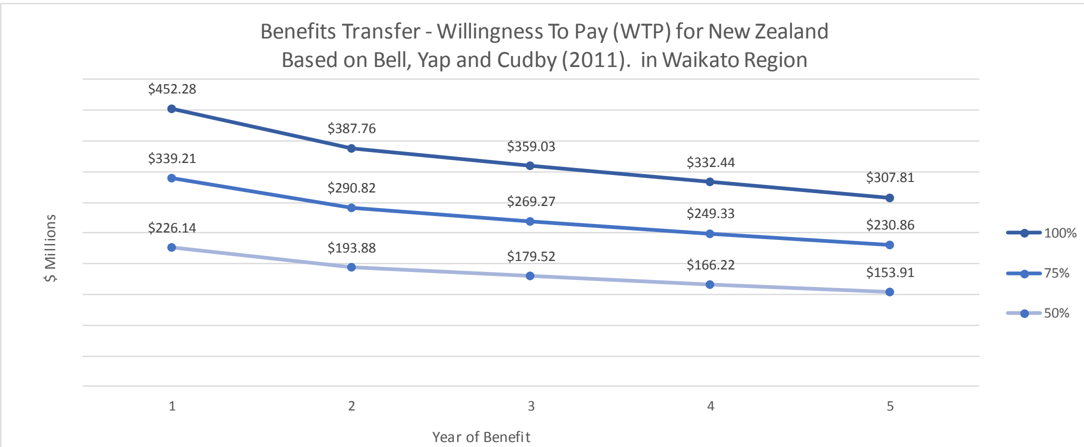

Figure 3. Benefit transfer results for E. hirsutum.

Transferring the WTP of NZD244 for the Waikato region to New Zealand as a whole, results in an annual WTP of NZD293 per household, or a total WTP of NZD920m if summed over 50% of the NZ population (Figure 2).

Conclusion

Hydrilla is a submerged macrophyte so is not directly comparable with *E. hirsutum* which is a littoral species, but *E. hirsutum* has the potential for major negative impacts on lake margins and wetlands. Even if the public's willingness to pay to prevent *E. hirsutum* from establishing was a tenth of that of *hydrilla* from the Bell et al. (2011) study, and assuming we can only aggregate these figures over 50% of the population, it would still represent an aggregate value of c$90 million over the next five years to avoid establishment of *E. hirsutum* in NZ.

A contingent valuation study investigating the preferences to avoid establishment of *E. hirsutum* may be worthwhile given the significance of this weed globally, and the high values associated with river and lake margins, and wetlands in NZ.

4.2.3 Example 2: Asterias amurensis (Northern Pacific Sea Star)[4]

Problem

Asterias amurensis (Northern Pacific sea star) is not known to be present in New Zealand. It has the status of ‘unwanted organism’ because of its likely high-very high impacts on economic, environmental, social and cultural values in New Zealand. *A. amurensis* grows quickly and forms high local population densities/swarms. It is capable of disrupting multiple species or species with high conservation value in subtidal areas e.g. wild mussels, scallop, horse mussel and dog cockle beds, on which many other species rely – for example crayfish consume dog cockles, and juvenile fishes use horse mussels for shelter. *A. amurensis* is a voracious feeder on wide range of species (bivalves, gastropods, barnacles, crabs, worms, other echinoderms, ascidians etc).

An estimate of the extent of the damages was required to inform whether resources should be allocated to a more robust NMV.

Primary study

A search of the literature for suitable source studies was conducted, with the following study found to be suitable for transfer between the source study and policy application[5]:

> Mazur, K., Bath, A., Curtotti, R., and Summerson, R. (2018). *An assessment of the non-market value of reducing the risk of marine pest incursions in Australia’s waters*. Canberra: ABARES.

Mazur et al. (2018) carried out a choice modelling study to estimate and value the non-market environmental benefits to the community from reducing the risk of marine pest incursions in Australia. The survey included questions about Australians’

[4] This case study was undertaken by Kathy Walls, MPI.

[5] It is important to consider the biophysical, population, scale of change and framing factors of the primary study compared to the policy site. See Tait and Rutherford (2018), Chapter 4, for details of this process.

willingness to pay for protection of a number of native species, and protection of a length of coastline and adjacent waters.

Application

Mazur et al. (2018) estimated Australian households' willingness to pay to protect native species from marine pests as AUD16.30 per species per household per year. Using the benefit transfer tool, and assuming the New Zealand public values marine species in a similar way, this amounts to NZD14.02 per household per year , or a total WTP of NZD44m or NZD88m if summed over 50% or 100% respectively, of the NZ population (Figure 3).

Conclusion

Total WTP is likely to be an underestimate of value because more than one native species of significance to New Zealanders will be impacted by *A. amurensis*. A tailored NMV investigating the preferences to avoid establishment of marine pests would be worthwhile given the lack of primary NZ studies currently available.

Basic Unit Value Transfer Report

Source Study

Source Study:	**Mazur et al. (2018) ABARES Technical Report 18.2**
Study WTP:	**$16.3 per household (HH)**
Study Year:	**2016**
Study Location:	**Australia**

Notes

0

Transfer Value Adjustments

Region of Benefits	**New Zealand**
Time span of bene	**5 years**
Discount rate:	**8%**
Scale:	**Same**
Substitutes:	**Same**

Transfer Values

Adjusted annual WTP/HH:	**$ 14.02**		
Total Present Value/HH:	**$ 57.02**		
% of Beneficiaries WTP:	50%	75%	100%
Total Aggregate Beneficiaries WTP:	$ 44,180,555	$ 66,270,832	$ 88,361,109

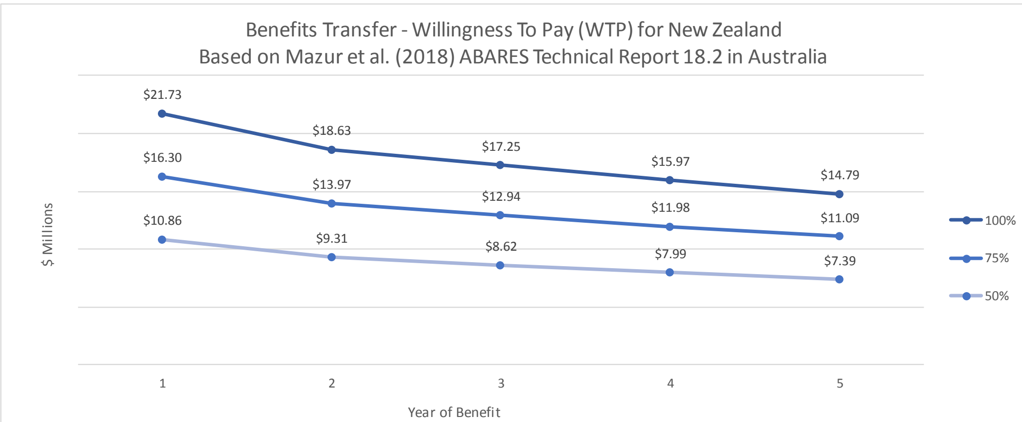

Figure 4. Benefit transfer results for *A. amurensis*.

5 Data Analysis

It was originally envisaged that data from incursion responses, undertaken by NZMPI 2004-05 to 2015-16, would be analysed to understand the following:

1. patterns in expenditure overtime by: pest type, sector affected, type of impact;
2. whether the characteristics of 'successful' eradications as discussed in Workshop 1 were borne out by the data;
3. whether NZMPI is getting 'better' at responding, e.g in terms of time taken to meet particular response activities.

Analysis of this data would show the typical shape of response spending by MPI over time, particularly whether this varied for type of pest and the sector affected, and whether patterns are changing over time. If patterns are indeed changing over time then additional analysis might reveal whether this is due to improvements in efficiency or due to other characteristics of the incursion.

The pattern of 'response spending' may take on a variety of shapes and some examples are presented in Figure 3. Understanding these curves, would allow for additional scenario analysis to be undertaken, for example, to understand the impact of increased spending earlier in the program, optimal expenditure patterns etc.

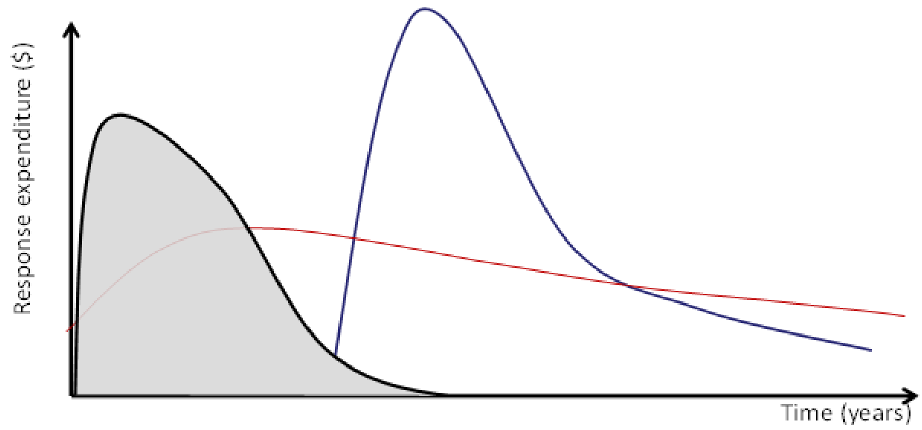

Figure 5. Hypothetical response-spending curves

5.1 Data

NZMPI supplied a spreadsheet of expenditure data on 55 incursion responses that occurred over the period 2001-05 to 2015-16. This spreadsheet was subsequently modified to incorporate information for each response, on the following:

1. Type of pest (insect, bacterium, fungus, weed, vertebrate, other invertebrate, virus, other);
2. Sector Affected (plant, environment, marine, animal, and/or people);
3. Whether impact would be on the environment, economy, human health or socio-cultural values;

Information on 1-3 for several responses was not available. These responses were removed from the spreadsheet.

Ideally it was hoped that data would be available from MPI's Response Tracker database on the following variables:

- Initiation Priority (from Response Tracker);
- Response outcome (eradicate, do nothing, manage etc);
- Date of initial detection (when found in the field);
- Date notified to MPI 0800;
- Date ID confirmed;
- Date of RAR;
- Date Response Activated;
- Date of Response Brief;
- Date of Business Case;
- Eradication, Transition to long-term management, or accepted establishment declared;
- Date of close out report;
- Level of readiness; and
- Response performance.

Analysis of this information would allow conclusions to be drawn about whether/where MPI had become more efficient at responding to incursions. Unfortunately, extraction of this data proved too resource intensive, given other response priorities, and it was halted.

The original dataset that remained was analysed using econometric techniques -- more details of the analysis is provided in Appendix C.

5.2 Summary of results

As previously mentioned, lack of resources to extract data prevented the in-depth analysis originally envisaged. However a random effects model could be conducted on summary variables over a pooled data set. The following results were found in the data analysis:

- The largest share of response spending has been directed to those incursions that directly affect agriculture relative to other sectors.
- Spending on incursions that affect the environment is falling behind incursions that affect agriculture, however, in reality there is very little difference in spending between the two sectors.
- Disease outbreaks in the North Island of New Zealand tend to receive the largest share of expenditure on managing pest and disease outbreaks.

6 Recommendations

The overarching purpose of this two-year project is to improve and strengthen MPI's decision making in response to new pest or disease incursions that may pose a risk to the economic, environmental, human health and socio-cultural values of New Zealand.

Activities during year one of the project identified non-market valuation as a key focus for year two of the project. Typically, these impacts are more challenging to value than market impacts. When non-market impacts are ignored, the resulting CBA will be incomplete. Depending on the size of non-market impacts, this may lead to inefficient resource allocation.

The economics discipline provides a range of rigorous and credible methods for valuing the non-market impacts of pest and incursions. Unfortunately, MPI staff with these skills are not always available to assist in developing the CBA and business cases for a response. Recommendations from this project focus mainly on improving CBA and the capacity of decision makers to incorporate NMV into decisions.

Key recommendations are that:

1. **when a CBA is developed during the response phase of an incursion, benefit transfer should be undertaken to screen the magnitude of potential environmental impacts.**

   The Excel-based 'benefit-transfer tool' developed in this project should be used to indicate the nature and scale of non-market impacts. This analysis may be done in-house, reasonably quickly, and only requires that similar, primary studies have already been undertaken. Results from using the tool would also indicate whether further investment in a larger primary NMV study is required.

2. **pre-emptive primary studies be undertaken on the non-market values of pest incursions**

   The economics discipline provides a range of rigorous and credible methods for valuing the non-market impacts of pest incursions. Unfortunately, most of these methods involve primary data collection through surveys, and may upward of six weeks and require significant resources to implement. The methods are therefore usually inappropriate for application in the time-critical response context of invasive marine species. Primary non-market valuation studies, undertaken 'pre-emptively', could provide a pool of data from which to make inferences about likely impacts of incursions once an incursion is notified. Of particular note is the lack of information on non-market impacts of marine pests and diseases. Investment in primary NMV studies should be viewed as an investment in response preparedness, which will potentially result in improved response management in the future.

3. **step-by step guidelines for undertaking CBA during the initial response phase be included in *Biosecurity Response: Cost Benefit Analysis***

   When staff who are not economists (or where assistance from economists is not available) are required to undertake CBA they will benefit from detailed guidelines or templates from which to develop a CBA. This will allow CBAs to be consistent and rigorous. A standard approach for undertaking a CBA should be adopted – a nine-step approach to CBA, developed by CEBRA, would provide a useful improvement to the current process. This incorporates NMV at step 5, thus embedding NMV in CBA.

4. **data be collected in a way that would allow for detailed analysis of response expenditure over time**

   In order for a meaningful analysis of response spending over time to occur, data on pest spread and expenditure on management inputs would need to be collected and stored in a way that is easily and readily accessible by the analyst. This data should also be reported in time steps of less than one year, and all costs of response expenditure would need to be recorded, including the cost of all MPI staff time.

5. **serious consideration be hiring an economist who specialises in NMV. NMV and embedding that individual within the response team**

   While a basic BT or CV could be carried out in house at relatively low cost, in a short time frame, and not require a high level of expertise in CBA or NMV, if a more robust estimates is required, then the expertise of a specialised NMV practitioner should be sought. The skills of such an individual – an applied economist who specialises in non-market valuation – would be an asset to the current response team. It would be beneficial for the economist to be embedded in the team and be dedicated to assisting with the development of CBAs, undertaking NMV, assisting in negotiation of tailored NMV with third-party contractors, and undertaking analysis of response data in order to understand changes in patterns of expenditure over time.

7 Bibliography

Barbier, E. B., Acreman, M. C. & Knowler, D. (1997). Economic valuation of wetlands: A guide for policy makers and planners. Ramsar Convention Bureau, Gland, Switzerland.

Bell B. A., Yap M., & Cudby C. (2009) *Valuing Indigenous Biodiversity in the Freshwater Environment*, In: Annual NZARES Conference. NZARES, Nelson, New Zealand.

Bell, B.A, Yap, M. and Cudby, C. (2011). *Biodiversity Valuation Manual: A technical manual for MAF BNZ (Revised)*. Nimmo-Bell & Company Ltd, New Zealand
Blanchard, O. & Sheen, J. (2013. *Macroeconomics*, 4th edition, Pearson Education Australia.

Commonwealth of Australia. 2006. Handbook of Cost Benefit Analysis. https://www.finance.gov.au/sites/default/files/Handbook_of_CB_analysis.pdf

Hofstra, D.E. & Champion, P.D. (2006). Management Options Assessment Report for *Hydrilla verticillata*. NIWA Client Report: HAM2006-159 Prepared for Biosecurity New Zealand, 23pp. Available at https://www.mpi.govt.nz/dmsdocument/16993-management-options-assessment-report-for-hydrilla-verticillata

Mazur, K., Bath, A., Curtotti, R., and Summerson, R. (2018). *An assessment of the non-market value of reducing the risk of marine pest incursions in Australia's waters*. Canberra: ABARES. Available at http://www.agriculture.gov.au/abares/research-topics/fisheries/fisheries-research/value-of-reducing-marine-pest-incursion-risk

Pascual, U. and Muradian, N, R. 2010. The Economics of Ecosystems and Biodiversity, in Kumar, P. (ed.), The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations, Earthscan.

Pearce, D. 1993. Economic values and the natural world, London, Earthscan Publications Ltd.

Rolfe, J, & Windle, J., 2015. Public preferences for controlling an invasive species in public and private spaces. *Land Use Policy*, 41, 1-10

Statistics New Zealand (2000). *All About the Consumers Price Index (A Layperson's Guide): 1999.* Available at: http://archive.stats.govt.nz/browse_for_stats/economic_indicators/CPI_inflation/about-consumers-price-index.aspx .

Stimson, J. A., Carmines, E. G., & Zeller, R. A. (1978). Interpreting polynomial regression. *Sociological Methods & Research*, 6(4), 515-524.

Tait, P and Rutherford, P. (2018). *Non-market valuation of environmental impacts for biosecurity incursion Cost Benefit Analysis: A guidance manual for public policy*, Agribusiness and Economics Research Unit, Lincoln University

8 List of Figures

9 List of Tables

10 Appendix A: Workshop 1

Table 2. Selected incursion responses and characteristics that differentiate them (output from workshop 1)

	Little known about the pest	Absence of effective controls	Significant non-market impacts	Effort and investment thought appropriate	External stakeholder expectations met	External stakeholder expectations not met	Large-scale response	TAG used	Lack of lure/trap
Recommended: GWCB			√		√ *	√		√	√
Didymo		√	√				√		√
ELB - Waikanae				√		√		√	√
European alpine newt	√		√			√			√
Harlequin ladybird			√			√			√
Painted apple moth			√	√	√ *	√ ^	√	√	
Queensland fruit fly				√	√		√		
Velvet leaf									√
Psa virus									√
Sabella									
Theileria									
Brown dog tick									
Tomato-potato psyllid					√				
Bonamia									
Indian ringneck parrot			√	√	√				√
Hadda beetle			√			√			√
Nematode (Hagley Park)									√

Possible: Chinese knotweed			√						√
Kauri dieback	√	√	√			√	√	√	√
Termites			√		√				
Sth’n saltmarsh mosq.			√		√		√	√	√ x
Tau fly					√		√	√	
Asian gypsy moth			√	√	√				
Batwing passionflower			√			√			√ x

11 Appendix B: Non-Market Valuation Guidelines

Tait, P and Rutherford, P (2018) *Non-market valuation of environmental impacts for biosecurity incursion Cost Benefit Analysis: A guidance manual for public policy*, Agribusiness and Economics Research Unit, Lincoln University

12 Appendix C: Data Analysis

Author: Dr Omphile Temoso

12.1 Data

NZMPI supplied a spreadsheet of expenditure data on 55 incursion responses that occurred over the period 2001-05 to 2015-16. This spreadsheet was subsequently modified to incorporate information for each response, on the following:

4. Type of pest (insect, bacterium, fungus, weed, vertebrate, other invertebrate, virus, other);
5. Sector Affected (plant, environment, marine, animal, and/or people);
6. Whether impact would be on the environment, economy, human health or socio-cultural values;

Information on 1-3 for several responses was not available. These responses were removed from the spreadsheet.

Ideally it was hoped that data would be available from MPI's Response Tracker database on the following variables:

- Initiation Priority (from Response Tracker);
- Response outcome (eradicate, do nothing, manage etc);
- Date of initial detection (when found in the field);
- Date notified to MPI 0800;
- Date ID confirmed;
- Date of RAR;
- Date Response Activated;
- Date of Response Brief;
- Date of Business Case;
- Eradication, Transition to LTM, or accepted establishment declared;
- Date of close out report;
- Level of readiness:
    - (Readiness plans in place (eg, response contingency plans);
- Response performance:
    - Success Measure (from Response Tracker);
    - RAM result (overall assessment);
    - Audit reports (eg, OAG report assessments);
    - Survey results (where exist);
    - Close-out report assessment of performance;

Analysis of this information would allow conclusions to be drawn about whether/where MPI had become more efficient at responding to incursions. Unfortunately, extraction of this data proved too resource intensive, and it was halted.

The dataset that remained was adjusted as follows:

- The total response expenditure for each incursion for a given year were calculated by adding all the expenses that include *contracts*, *logistics* and *operating costs* in eradicating or responding to the disease or pest by the MPI and other agencies.

- Data on nominal spending was deflated using the annual Consumer Price Index (CPI) from Statistics New Zealand, in order to examine changes in 'real' (rather than nominal) spending. A CPI deflator, rather than a GDP deflator, was used to convert nominal spending into the base year (2004-05) dollars as price impacts on government expenditure depend mainly on consumer prices and nominal wages[6]. The following formula was used to convert nominal expenditure to real expenditure:

  Real Expenditure = Nominal Expenditure / Consumer Price Index

12.2 Analysis

12.2.1 Response cost curves

Response cost-curves were analysed to show the pattern of expenditure on different incursions, and whether the pattern has changed (improved) over time. It is important to discover whether any change is due to changes in efficiency. A polynomial (quadratic) model explains the change in Y (expenditure on response) over the time as follows:

$$Y = B_0 + B_1X + B_2X^2 + e \qquad (1)$$

where X = time, X^2 is a vector whose elements are squares of corresponding elements X, e is the error term and B_0, B_1, B_2 are the least squares coefficients to be estimated. Results of the estimated polynomial (quadratic) regression models for the biosecurity incursions in New Zealand for the period 2004 to 2016 are presented in Table 3.

Table 3. Logistic Regression Models for Expenditure on Biosecurity Incursions in NZ

Incursion	Regression Models	R-Squared
Queensland Fruit fly	$y = -0.4188x^2 + 4.1793x - 2.831$	0.854
Ants-Jellicoe Wharf[7]	$y = -0.1393x^2 + 1.7318x - 0.4632$	0.735
Ants-BAH069	$y = -0.3223x^2 + 2.9172x - 1.9428$	0.727
Nelson Termites	$y = -0.1452x^2 + 1.8478x - 0.6191$	0.774
Subterranean Termites	$y = -0.7071x^2 + 5.2517x - 3.9252$	0.831
Red Imported Fire Ants	y = -1.6462x2 + 10.067x - 8.064	0.916
PSA Kiwifruit	$y = -1.3605x^2 + 7.98x - 6.3548$	0.911
European Alpine New	$y = -1.1211x^2 + 7.3664x - 5.9091$	0.901
Painted Apple Moth	$y = -1.7467x^2 + 10.584x - 8.5086$	0.932
Eucalyptus Beetle	$y = -0.8187x^2 + 5.9249x - 4.5239$	0.860

[6] More information on CPI deflators can be found at Statistics New Zealand (https://www.stats.govt.nz/) and Statistics New Zealand (2000). For information on using CPI vs GDP deflators see Blanchard and Sheen (2013).

[7] This moved to a general surveillance programme for ants following an initial response.

GWCB	$y = -0.1464x^2 + 1.8614x - 0.4344$	0.670

However, it has been proven by Stimson et al. (1978) that the coefficients of a polynomial (quadratic) regression model cannot be easily or readily interpreted, partly because they are non-comparable. The reason for the non-comparability and ultimately the un-interpretability of the B_l and B_2 coefficients in polynomial regression is that the terms in the equation tend to be highly collinear (Stimson et al, 1978). Therefore, to address awkwardness of format and resulting un-interpretability of polynomial (quadratic) regression models, Stimson et al (1978) proposed a single algebraic manipulation of the equation (1) and this can be rewritten in the equivalent form:

$$Y = M + B_2 (F-X)^2 \qquad (2)$$

where: $M = B_0 - B_1^2 / 4B_2$
$F = - B_1 / 2B_2$

M is either the minimum or maximum value of the curve, B_2 is equal to B_2 in the polynomial regression format – the coefficient B_2 tells both the direction and steepness of the curvature (a positive value indicates the curvature is upwards while a negative value indicates the curvature is downwards) – and F is the value of X that produces a minimum (for concave upward) or maximum (for concave downward) value of Y.

It provides the essential information about a quadratic equation: where the curve reaches its maximum or minimum, "F," and what value it attains at that point, "M." Rewriting the regression models for Queensland fruit fly and Ants-Jellicoe Wharf in more interpretable form, we get:

Queensland fruit fly: $Expenditure = 12.12 - 0.419\ (4.99 - Time)^2$
Ants-Jellicoe Wharf: $Expenditure = 6.21 - 0.139\ (6.22 - Time)^2$

The difference between Queensland fruit fly and Ants-Jellicoe Wharf response curves is now easily observed. Expenditure for both fruit fly and Ants are convex downward.

The rest of the regression models estimated with a model proposed Stimson et al (1978) are presented in Table 4.

Table 4. Modified Regression Models (based on Stimson et al, 1978)

Incursion	**M**	**F**	**$Y = M + B_2 (F-X)^2$**
Queensland fruit fly	12.116	4.990	$y = 12.12 -0.419 (4.99-X)^2$
Ants-Jellicoe Wharf	6.214	6.216	$y= 6.21 - 0.139 (6.22 - X)^2$
Ants-BAH069	8.108	4.526	$y = 8.108 -0.322(4.53 -X)^2$
Nelson Termites	6.945	6.363	$y = 6.945 - 0.145 (6.36-X)^2$
Subterranean Termites	11.139	3.714	$y = 11.139 -0.707(3.71-X)^2$
Red Imported Fire Ants	16.615	3.058	$y=16.615 - 1.646(3.058 - X)^2$
PSA Kiwifruit	12.869	2.933	$y = 12.869 -1.361 (2.933 -X)^2$
European Alpine Newt	13.418	3.285	$y=13.418 - 1.121 (3.285 - X)^2$
Painted Apple Moth	17.251	3.030	$y = 17.251 - 1.747(3.03 -X)^2$
Eucalyptus Beetle	12.101	3.618	$y = 12.101 - 0.819(3.618 - X)^2$
GWCB	6.658	6.357	$y = 6.658 - 0.146 (6.357 - X)^2$

Note: $Y = M + B_2 (F-X)^2$; $M = (B_0 – B^1{}_2) / 4B_2$ and $F = - B_1 / 2B_2$

The negative coefficient of the quadratic equation (-1.36) for PSA Kiwifruit implies expenditure has been decreasing by $1.36 as time increases.

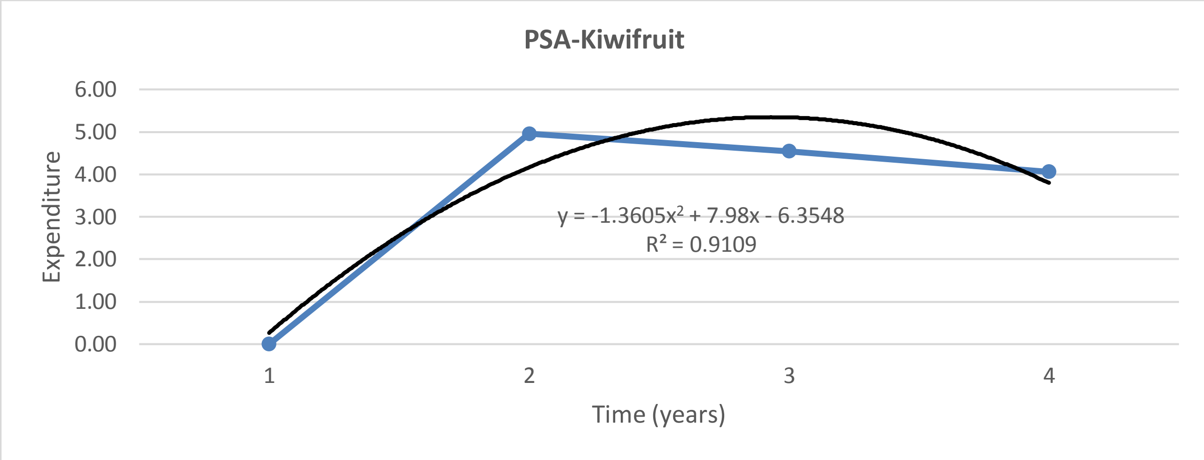

Figure 6. Response spending curve for PSA in kiwifruit

Figure 5 shows that the incursion response curve for *PSA Kiwifruit* had a large increase of spending at the initial stage (first year), followed by a declining trend of expenditure the following periods. This implies that, the MPI have been quick to respond and able to achieve its management goal faster and cheaper.

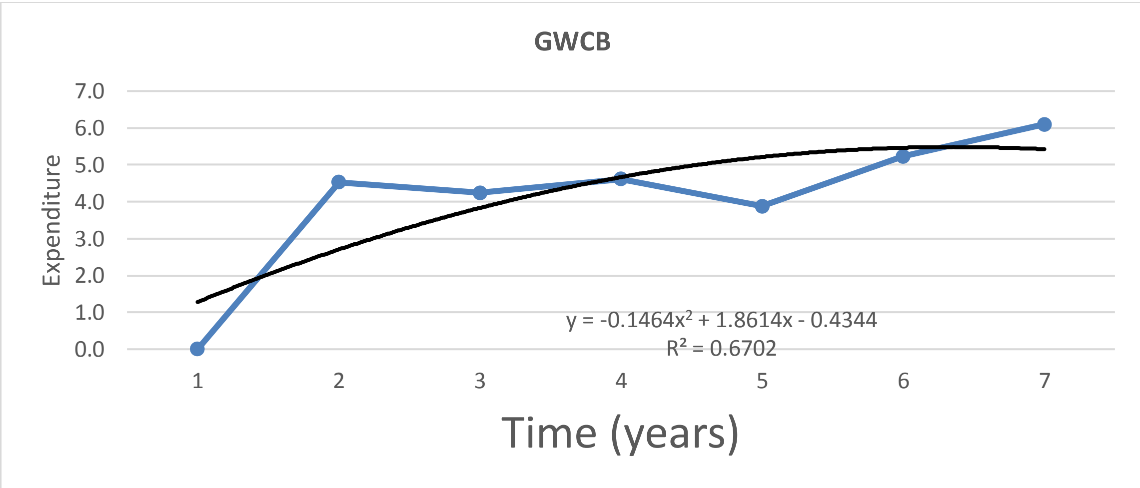

Figure 7. Expenditure patterns for Great White Cabbage Butterfly

In the case of Great White Cabbage Butterfly, the response curve increased sharply during the first year, followed by a constant growth in the next four years, then slight increase in the final year of the study period (Figure 6). This implies that the MPI may have been slightly slower in responding to the incursion in the first few years and were able to dedicate more resources in the following period. It is important to note, however that the Department of Conservation (DOC) continued with this response, and DOC expenditure on the response is not included in this analysis.

Response curves for termites, red imported fire ants and other ants are shown in Figures 7-9. Overall, the various response curves shows two main patterns, one group of curves shows an increased effort early on (i.e. lots of money is spent early on or as soon as an outbreak is established), implying that the MPI (and other agencies) are achieving management goals faster and more cheaply. The other pattern is whereby spending have been gradually increasing over time, which would imply that MPI has been slow to respond to an outbreak. It is important to note, however, that subterranean termites require a period of 5 years after elimination before eradication can be declared.

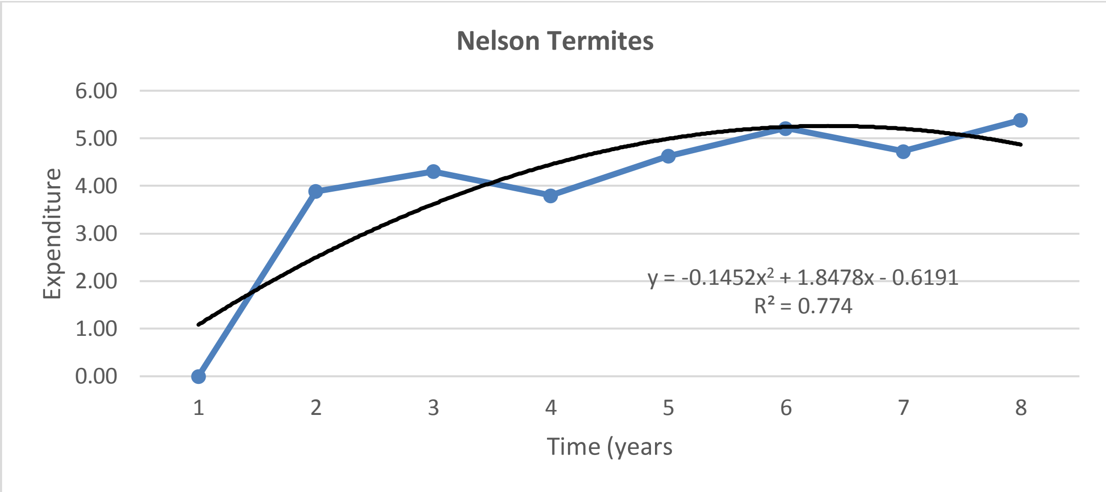

Figure 8. Response Curves for Termites in NZ

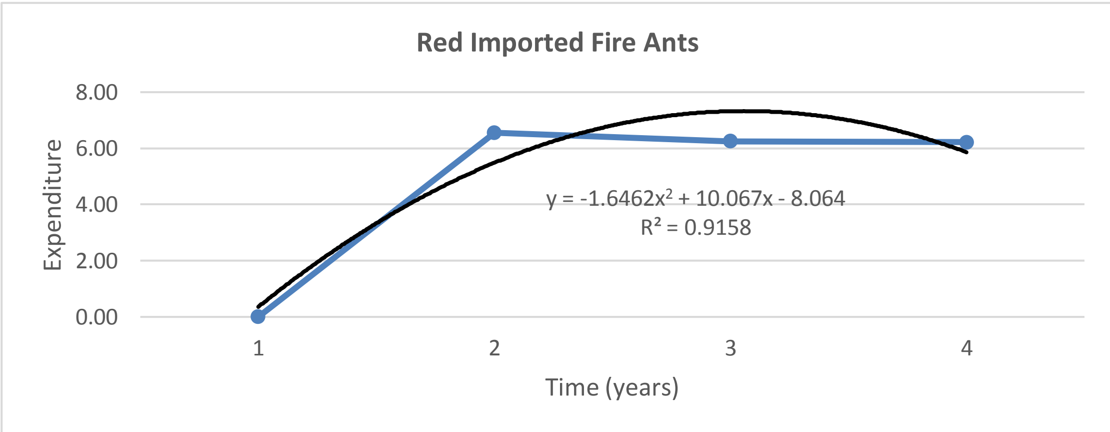

Figure 9. Response spending curve for Red Imported Fire Ant

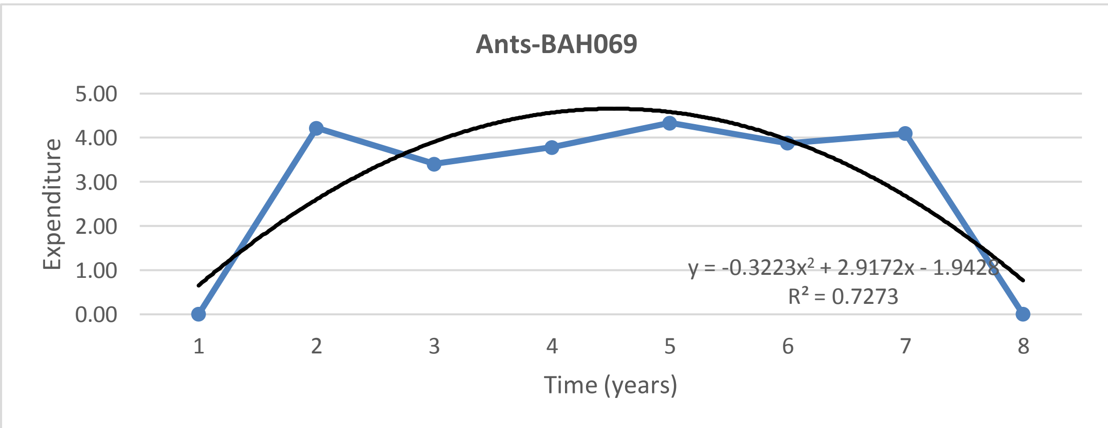

Figure 10. Response spending curves for Ants- BAH069

12.2.2 Identify the average response duration/timings (days) patterns for different incursions

We use different incursions of QFF to demonstrate the time (duration) it takes the MPI to response to an outbreak (Figure 10). The longest time taken between the disease outbreak and its eradication was for QFF 600928 which took approximately 700 days[8], whilst the least days were for the QFF 600924, which only took 56 days.

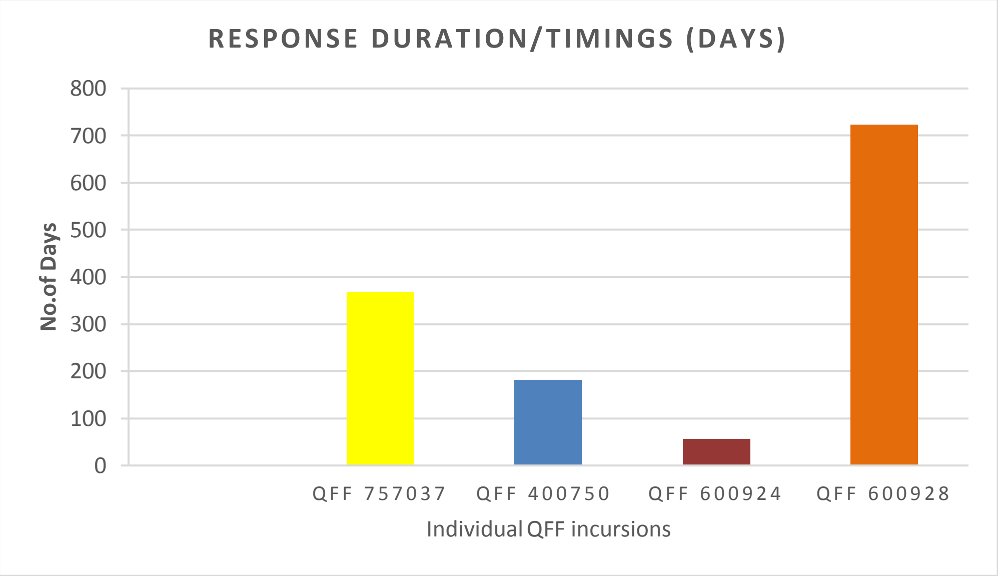

Figure 11. Response duration

12.2.3 Expenditure patterns

It was of interest to understand patterns in expenditure overtime by pest type, sector affected, and type of impact. This was undertaken using panel data models. These allow individual incursions to be followed over time, allowing an understanding of the dynamics of spending on a given incursion.

Panel data models may be used to explain the causes of change in incursion response spending, thus giving us an opportunity to investigate both the level and flows between various amounts spent, and thus establishes links of causal relationships among different incursion responses and series of spending. They also provide an opportunity to correct for the correlation of independent variables with unobservable and fixed factors influencing incursion response spending. Observed differences in incursion spending may be attributed to observed differences (e.g.; type of pest, region, sector affected). Panel data can account for both inter-temporal and spatial aspect of incursion responses, and so allows causality to be attributed to changes (or differences) in individuals' characteristics, or to exogenous characteristics.

There are two main types of panel data models that we can choose from, *fixed effects* and *random effects model*.

Fixed Effect Model:

[8] It is important to note that incursion involved a breeding population being detected, hence the longer duration before eradication was achieved.

A fixed effect model (FEM) is of use in analysing the impact of variables that vary over time. When using FEM we assume that something within the individual model may impact or bias the predictor or outcome variables and we need to control for this. This is the rationale behind the assumption of the correlation between entity's error term and predictor variables. FEM remove the effect of those time-invariant characteristics so we can assess the net effect of the predictors on the outcome variable.

Random Effect Model:

An advantage of a random effects model (REM) is that time-invariant variables may be included (i.e. region, sector). In the fixed effects model these variables are absorbed by the intercept.

The econometric models can be presented as ordinary least squares as follows:

$$\ln Y_{it} = \alpha_i + \beta_1 \ln X_{1it} + \beta_2 \ln X_{2it} + ... + \beta_n \ln X_{nit} + u_{it} + \varepsilon_{it} \qquad (1)$$

where:

Y_{it} is the dependent variable (natural logarithm of expenditure for the incursion) and i = incursion and t = time;
X_{int} represents one independent variable (IV);
α_i represents the intercept;
β represents the slope coefficients to be estimated, and
ε_{it} represents the regression residuals.

Choosing between Fixed and Random effects models

The Hausman test is used to choose between the two models. The null hypothesis is that the preferred model is REM vs. the alternative the FEM:

- If the p-value for the Hausman test, is < 0.05 then the random-effects estimator is not good. The fixed-effects estimator is consistent; however, the random-effects estimator is more efficient.
- On other hand, if the estimates using random effects are not significantly different from the fixed-effects estimator (i.e., the p-value is > 0.05) then you can retain the random-effects estimator.

After testing between different panel data models, and using the Hausmann test, the REM was chosen (i.e., 0.612 is significantly larger than the 0.05 (95% percent)). Results from the REM are given in Table 5. There are only four significant dummy variables : agriculture, environment, marine and NI (North Island).

In terms of the impact of the sector, we find that spending on agriculture is highly significant, followed by environment and marine, whilst people (urban environment) is not significant. These results imply that the largest share of spending have been directed to those incursions that directly affect agriculture than any other sectors in New Zealand. It is worth noting that cost to agriculture is generally more easily identifiable and therefore will be more available.

The environment dummy variable is used to compare spending on incursions that affect environment relative to other sectors. The environment coefficients is positive and implies that spending on the environment is falling behind that of the base sector (economy). However, this variable is not significant hence there is not much difference between the two sectors.

NI represents the dummy variables for the two main Islands in New Zealand (North and South Island) where the disease outbreaks were found. The variable takes a value of 1 for North Island and 0 for the South Island. Results in Table 4 show that the location variable (NI) is positive and significant compared to the South Island. This means disease outbreaks in the North Island tend to receive the largest share of expenditure on disease outbreaks.

Table 5. Results from the REM model.

logy	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
insect	-0.208	0.468	-0.450	0.656	-1.125	0.708
bacteria	-0.406	0.537	-0.760	0.449	-1.459	0.646
vertebrate	0.121	0.535	0.230	0.821	-0.928	1.170
other	-0.261	0.502	-0.520	0.604	-1.244	0.723
agriculture	**5.085**	**0.110**	**46.250**	**0.000**	**4.869**	**5.300**
environment	**3.907**	**0.196**	**19.930**	**0.000**	**3.523**	**4.292**
marine	**5.769**	**0.344**	**16.760**	**0.000**	**5.094**	**6.444**
people	-0.140	0.266	-0.530	0.598	-0.661	0.381
NI	**0.613**	**0.134**	**4.580**	**0.000**	**0.351**	**0.876**
t	-0.005	0.011	-0.410	0.681	-0.026	0.017
_cons	0.145	0.469	0.310	0.758	-0.775	1.064
Overall R^2	0.963					
No. of Obs	192					
Number of Groups	16					
Wald chi2(10)	5153.89					