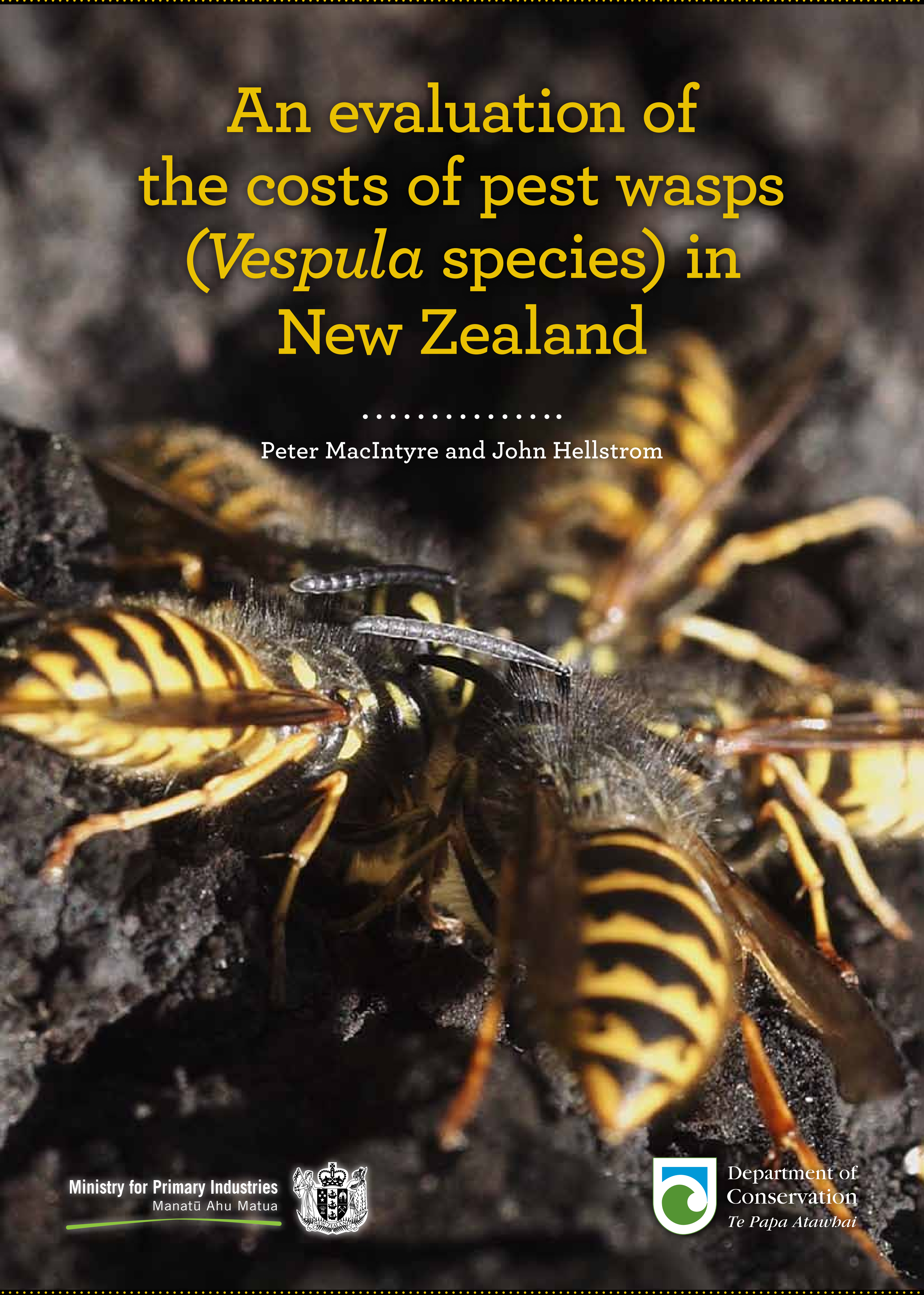

# An evaluation of the costs of pest wasps (*Vespula* species) in New Zealand

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Cover: Common wasps *Vespula vulgaris* on black beech *Fuscospora solandri*, Pelorus Bridge. *Photo: James Reardon.*



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# Contents

# Executive summary

This study assessed the economic impact of German wasps (*Vespula germanica*) and common wasps (*V. vulgaris*) across industries, society and the natural environment in New Zealand.

This assessment was based on a literature review, the use of 'total economic value' (TEV) and 'natural capital / ecosystem services' frameworks to identify knowledge gaps, surveys, and the quantification of net effects and trends where possible. A science and stakeholder group known as the Wasp Tactical Group tested any assumptions.

Information was collected from previous studies and from affected sectors in New Zealand to estimate the total costs of wasps, i.e. the costs that could be avoided and the opportunities that could be gained if wasps were not present in New Zealand, to get a sense of the overall scale of the wasp problem. The focus was largely on direct net cash flow changes should wasps be removed. No multiplier effects flowing on into the economy were included, although these would be expected to significantly increase the total benefits estimated. This study did not explore the marginal benefits of any particular control method for wasps.

The focus was targeted on sectors in which the impact of wasps appeared largest. Monetary, non-monetary, qualitative and quantitative benefits and losses were included, as in a number of areas it was not possible to quantify the net benefits. There were some areas of investigation in which further work might yield useful quantifiable benefits and costs, however.

Where it was possible to estimate the net effect of wasps, a total annual economic cost was calculated. A net present value (NPV) of the net effect of wasps on New Zealand from 2015 until 2050 was also calculated, which covered 36 years and followed the approach used by the former Ministry of Agriculture and Forestry (MAF) in its economic impact assessment of *Varroa* mites on honey bees (*Apis mellifera*) in November 2000.

The diagram at the end of this summary outlines the key findings. The direct impacts of wasps were estimated to cost New Zealand $75 million per annum or $772 million from 2015 to 2050 (NPV). Around 80% of this value was derived from removing the impact of wasps on bees and the flow-on benefits to pastoral farming through the increased pollination of nitrogen-fixing clovers. This would lower the need for nitrogen fertiliser and clover oversowing, which would benefit the pastoral sector. Wasps also had direct impacts on animal health, forestry, arable farming, horticulture, human health and traffic crashes. No significant effects of wasps on viticulture were identified.

A significant option value was also identified for apiculture development around the upper South Island beech forests, which represents the benefit of the resource in the future should wasps be removed. This totalled $58 million per annum or an NPV of $578 million in the period 2015 to 2050. These beech forests contain considerable numbers of wasps, which feed on the rich honeydew produced by scale insects that feed on the beech trees. In the absence of wasps, bees would be able to significantly increase their harvest of this honeydew, which could substantially increase honeydew honey production. More than 95% of the honeydew that was no longer consumed by wasps would also be available to other fauna, such as tūī (*Prosthemadera novaeseelandiae*), bellbirds (*Anthornis melanura*), kākā (*Nestor meridionalis*) and insects, as well as for other natural processes in the beech forest ecosystem. The removal of wasps from these forests could therefore greatly improve biodiversity, recreational and tourism value.

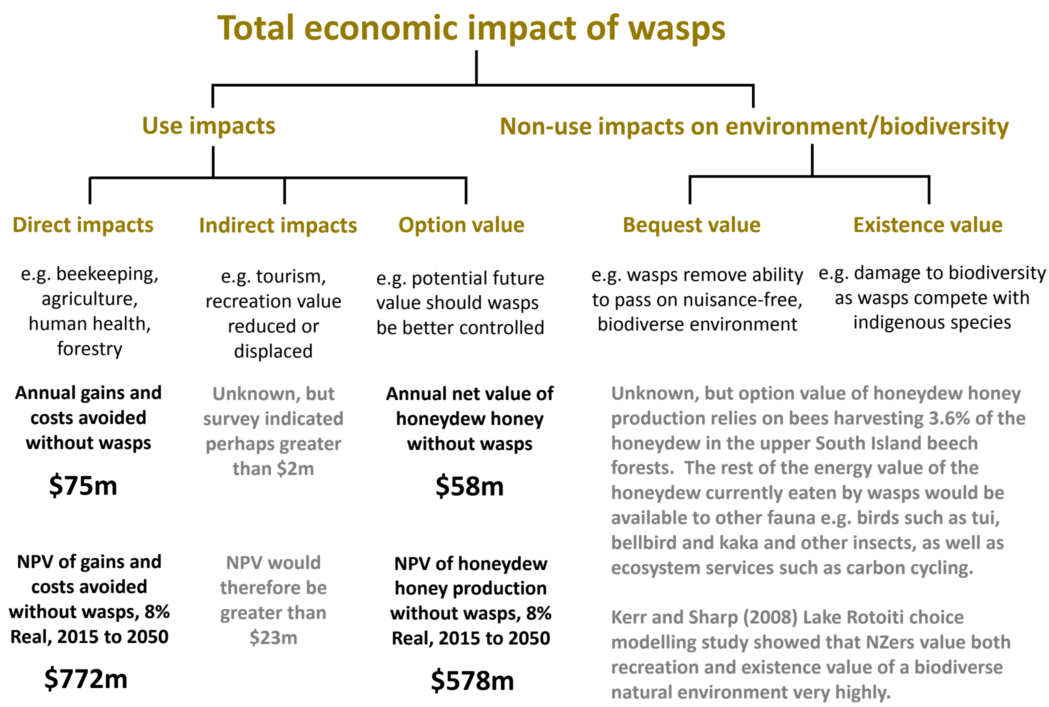
Addition of the quantified direct use costs and option value impacts gives a point estimate annual cost of $133 million or an NPV of $1,350 million attributable to wasps.

To investigate some of the indirect impacts of wasps, recreational groups were surveyed to explore whether wasps might lead to reduced or displaced recreation and tourism. It was found that wasp impacts were particularly large in areas near the upper South Island beech forests, where wasp populations can be very large. Other hot spots included the Waitakere Ranges and Waikaremoana. Based on the small number of people surveyed, we calculated a conservative value of recreation lost of $2m per annum as a result of wasps.

Wasps also have non-use impacts. The value of bequeathing a wasp-free biodiverse environment and knowing that such an environment exists is unknown. However, the option value of honeydew honey apiculture and the findings of Kerr & Sharp's (2008) study of South Island households' willingness-to-pay for better management of wasps indicate that New Zealanders could get considerable value from the suppression of wasps, with most of that value coming from the upper South Island beech forests.

Although some data were collected, it was not possible to properly quantify the impacts on all of New Zealand's regional councils and unitary authorities—although the data that were gathered suggested that the total costs were moderate relative to the other values estimated. It was also not possible to quantify the benefits gained from the export of wasp products or the sale of wasp-control products, or to identify unambiguous economic or ecological benefits from wasps, which potentially control other pest insects.

Some of the key impacts of wasps were sensitivity tested. By using the lower estimated values for these, and making some allowance for the impacts of wasps on non-use impacts on the environment and biodiversity, and indirect impacts on tourism and recreation, a lower bound of around $700 million NPV in the period 2015 to 2050 is likely. By contrast, the upper bound of the net impact of wasps could be an NPV of $2 billion or more.



# 1. Introduction

German wasps (*Vespula germanica*) and common wasps (*V. vulgaris*) have significant impacts on biodiversity in New Zealand, and also affect a wide range of industry sectors. Wasps are a nuisance and a human health hazard, and so affect outdoor activities (particularly where numerous), which in turn affects recreation, tourism and other economic activities. In addition, wasps can have direct impacts on the primary sector, particularly through their effect on honey bees (*Apis mellifera*).

Historically, the development of *Vespula* wasp control has been largely funded by the conservation sector due to the biodiversity impacts of wasps, while other sectors have tended not to consider *Vespula* wasps a high priority for research. However, it is becoming increasingly apparent that wasps have significant impacts on a much broader range of sectors, making it timely to consider the economic costs of these pests to New Zealand.

## 1.1 Objective and scope

The objective of this study was to obtain a robust quantitative understanding of the impact of *Vespula* wasps across sectors in New Zealand to give a more balanced understanding of their total impact.This was done by:

- Reviewing existing peer-reviewed and grey literature to assess trends and identify the costs/benefits of wasps.
- Using 'total economic value' (TEV) and 'natural capital/ecosystem services' frameworks to identify any cost/benefit information gaps.
- Approaching, surveying or interviewing affected industries/sectors and subject matter experts to address any significant gaps.
- Collating impact estimates (likely to be a combination of dollar and non-dollar metrics and qualitative) for each sector and aggregating these nationally.

Where feasible and appropriate, the impacts were converted into current dollar values. All of the data were run past the Wasp Tactical Group (a science and stakeholder group established to inform science and the public with respect to management of pest wasps) to check whether the assumptions and analyses were realistic.

Common wasp *Vespula vulgaris* at Lake Rotoiti, Nelson Lakes National Park. *Photo: Eric Edwards.*

Time constraints and limited data availability necessitated a broad, national-level analysis, with the objective of achieving a relative quantification of the total impact of *Vespula* wasps across the identified sectors. Although it could have been of value to research each of these sectors using a variety of more detailed techniques, such as non-market valuation approaches, this was not possible in the 5 weeks available.

This study investigated the costs of *Vespula* wasps that would be avoided and the opportunities that could be gained should these wasps be removed from the New Zealand landscape. On the other side of the ledger, the report only includes benefits of wasps that would be foregone should wasps be removed, such as those stemming from the export of wasp larvae, venom, etc. It did not assess any costs associated with the research, development or implementation of programmes that may lead to their removal. However, the findings may provide some indication of the value that could be gained from such expenditure.

# 2. Methodology

In this study, we followed the approach used by Nimmo-Bell in its report for the former Ministry of Agriculture and Fisheries (MAF) Biosecurity on the economic costs of pests to New Zealand (Giera & Bell 2009), whereby information was collected from previous studies rather than by conducting new analyses on individual pest species.

Giera & Bell (2009) noted that to obtain an indicative estimate of the economic costs of pests to New Zealand, many introduced plant and animal pests needed to be assessed, along with the complex interactions these have on New Zealand's primary production systems, health, cultural and amenity values. They also pointed out that few studies had estimated the economic costs of animal and plant pests to the economy, highlighting the benchmark study of Bertram (1999) as one of the few that had.

In this study, Bertram (1999) split the measurable economic cost of pests (which included wasps) into two major components:

- Defensive expenditures: The financial cost of resources devoted to restricting pest populations
- Output losses: The economic output lost each year as a result of the existing level of infestation

Giera & Bell (2009) noted that other costs could also be measured in economic terms, such as recreational losses and environmental impacts (e.g. biodiversity loss). Therefore, in the present study, we sought to encompass Bertram's (1999) cost components and some of these other economic costs, as shown in Fig. 1.

For the purposes of this study, economic benefit (or loss) was defined as a gain (loss) in the welfare of New Zealand or New Zealanders from the eradication of wasps. The focus is largely on first-order cash flow effects. However, benefits and losses can be monetary or non-monetary, qualitative or quantitative, and so it is important that all of these varied inputs are considered. Therefore, we used a 'total economic value' (TEV) approach to achieve this.

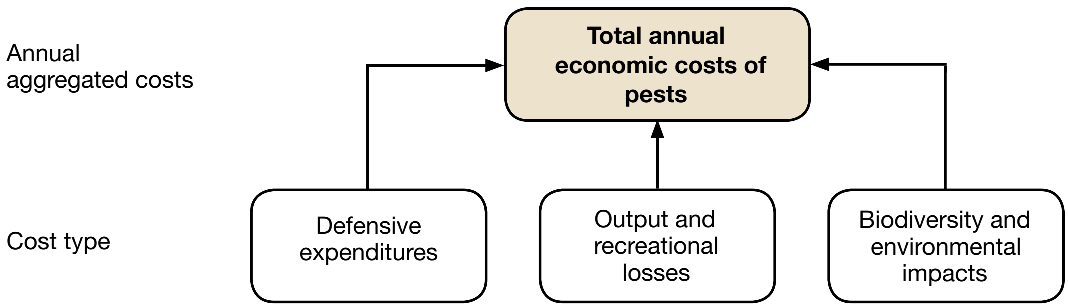



Figure 1. Components of the costs of wasps. *Source: Giera & Bell (2009).*

## 2.1 Total economic value and ecosystem services

The concept of TEV provides a means of demonstrating and understanding values and costs that can be attributed to a particular natural resource compared with not having it. In this case, it refers to the costs (and benefits, if any) associated with wasps, compared with the scenario where wasps are absent. Using the TEV approach, both the 'direct' and 'indirect' impacts of wasps are considered important, despite the fact that many are not directly priced in markets. TEV requires dispersed information to be put into dollar terms, where possible, and for quantitative and qualitative data to be aggregated to get an appreciation of the net effect.

The 'natural capital/ecosystem services' approach (Daily 1997) can also be used to understand the value of natural resources. Within this framework, the consideration of 'natural capital' seeks to ensure that nature's contribution to economies and human wellbeing is recognised, as well as other types of capital such as human, social and financial. 'Ecosystem services' are 'the benefits people obtain from ecosystems' (MEA 2003), which include provisioning services, such as food and water; regulating services, such as regulation of floods, droughts, land degradation and disease; supporting services, such as soil formation and nutrient cycling; and cultural services, such as recreational, spiritual, religious and other benefits. These concepts are pertinent to capturing the economic effects (both positive and negative) of *Vespula* wasps in New Zealand.

In this report significant ecosystem services affected by wasps are identified, but valuation of these affects within this framework was not attempted. We used the TEV approach to consider wasp impacts, as shown in Fig. 2.

The 'Use impacts' of wasps are separated into:

- Direct and indirect impacts, which arise from wasps affecting people's ability to earn or enjoy a private benefit, e.g. beekeeping or bush walking.
- Option value, which refers to the benefit from the possibility of using a resource in the future[1]. This might be the value that could emerge should wasp populations be better controlled. An example is the potential for greater honeydew honey production from beech forests.

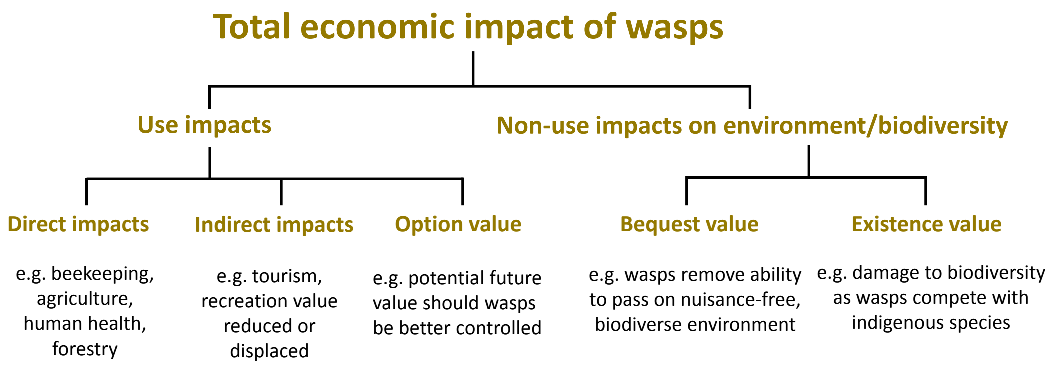



Figure 2. Total economic value (TEV) approach for the assessment of *Vespula* wasp impacts in New Zealand. *Source: Sapere adaptation of various TEV approaches.*

[1] Option value is placed under 'use impacts' in this study, but can also be considered a non-use bequest of existence value. Another form of option value within TEV is quasi-option value, which describes the gain from delaying a decision when there is uncertainty about the payoffs of choices available and when at least one choice involves an irreversible commitment of resources.

Non-use impacts on the environment and biodiversity arise from somebody knowing about the opportunities that could exist were wasp populations better managed—people perceive a value from knowing that forests are not infested with wasps even if they might not go there. These impacts are separated into:

- Bequest value, which is the value of a resource being available for future generations, whether or not it is currently used. For example, Kerr & Sharp's (2008) Lake Rotoiti choice modelling study showed that not only were households willing to pay to better manage wasps at that time, but they would also like to pass the possibility of increased biodiversity and better recreation opportunities on to the next generation.
- Existence value, which is the value of knowing that a particular environmental asset exists. An example of this would be the value associated with the knowledge that the chances of an endangered species being protected would improve if the pressure from wasps were removed.

## 2.2 Valuation approach

For the purposes of this study, we targeted our efforts on areas where we believed that wasps had the greatest impact.

Where it was possible to quantify the net effect of *Vespula* wasps, we estimated a total annual economic cost. We also calculated a discounted cost of the net effect of wasps from 2015 to 2050, or NPV of removing wasps. This covered 36 years and followed the approach used by the former MAF Policy in its November 2000 economic impact assessment of varroa in New Zealand (MAF 2000)[2].

*Vespula germanica* queens and drones, Queen Charlotte Sound. *Photo: Eric Edwards.*

When calculating the NPV, we used an 8% default real discount rate (real weighted cost of capital (WACC)), as recommended by The Treasury (2008). At this discount rate, a dollar of benefit or cost in 20 years' time (2034) would be worth 21 cents today and that same dollar after 36 years (2050) would be worth only 6 cents today (Fig. 3)[3]. The Treasury Cost Benefit Analysis Primer[4] recommends using a 20-year analysis period and adding on a terminal value. However, we decided to retain the approach adopted by MAF Policy because the two approaches would give similar results.

The 8% discount rate represents the return that an investor (such as the New Zealand Government) would expect to receive on some other proposal of equal risk. The Treasury pointed out that this discount rate takes account of:

- The 'rate of time preference', as most people prefer to be rewarded now for deferring consumption rather than at some point in the future.
- Uncertainty/risk: Since there is some uncertainty as to whether a future dollar will actually be received, a future dollar is of less value, in line with the level of uncertainty/risk of investing in the project.

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[2] Varroa is a genus of parasitic mites that attack honey bees. MAF Policy modelled the impact of varroa on bees and the flow-on effects on New Zealand over 35 years from 2001 to 2035.

[3] The 36-year analysis period leaves only 6% to be accounted for in a terminal value.

[4] Treasury Cost Benefit Analysis Primer , Version 1.12, December 2005.

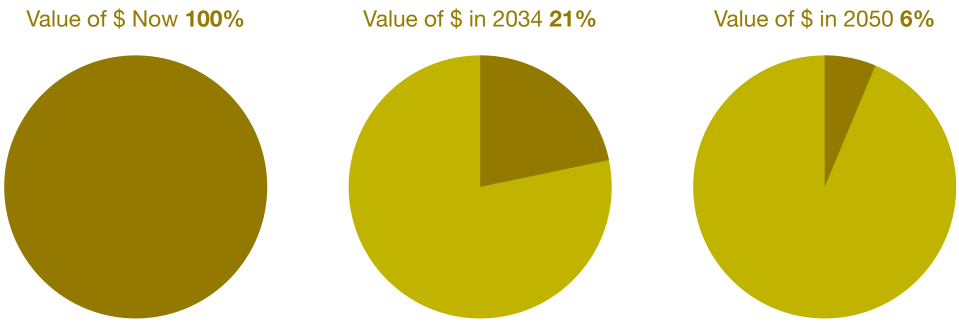


Figure 3. Impact of 8% discount rates on value over time. *Source: Sapere.*

The 8% discount rate also signifies in one number how much decision makers care about the future compared to today. There are arguments that other discount rates should be used (see Young 2002; NZIER 2011), and so the effect of varying the discount rate is tested in a sensitivity analysis at the end of this report (section 4.3).

The focus of this report was largely on direct net cash flow changes that would occur directly should wasps be removed. No multiplier effects were included, which would provide a measure of flow-on effects of any changes in revenue through the rest of the economy via increased employment and gross domestic product (GDP) output. Such effects would be expected to significantly increase the total benefits estimated.

Where it was not possible to quantify the costs/benefits but we believed that the effect could be material, we sought to undertake a qualitative analysis. We also highlighted those areas of investigation in which further work might yield useful quantifiable costs and benefits.

Beehives with both mānuka *Leptospermum scoparium* and kānuka *Kunzea ericoides* vegetation in background near Lake Rotoiti, Nelson Lakes National Park. *Photo: Eric Edwards.*

# 3. Sector impacts

In this section, we investigate the direct impacts that *Vespula* wasps have on New Zealand by estimating their cost to primary industries, human health, traffic accidents, and regional councils and unitary authorities. We also explore their indirect impacts on recreation and tourism, and non-use impacts on the environment and biodiversity.

## 3.1 Primary industries

### 3.1.1 Apiculture—direct hive effects

Table 1. Apiculture costs as a result of wasps. *Source: Sapere and John Hellstrom analysis.*

| WITHOUT WASPS THIS IS POSSIBLE | APICULTURE SECTOR KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Avoided wasp control management costs | $5 per hive per year for managing wasps and hive numbers increasing at 5% for 5 years followed by static numbers | $2.5m | $34.3m |
| Avoided cost of hives lost to wasps | 5% loss of hives each year, replaced with 1 kg of bees + queen, 25 kg sugar and loss of half EBIT of hive; same assumptions about hive numbers as above | $3.6m | $49.7m |
| Production gain from bees focusing on harvest | 5% improvement in EBIT per hive as bees focus on food collection rather than defence against wasps; same assumptions about hive numbers as above | $2.7m | $37.3m |
| Total | | $8.8m | $121.3m |

Table 1 summarises the estimated costs of wasps to apiculture in New Zealand.

Both common and German wasps cause losses to apiculture by killing bees and their larvae for protein, and robbing hives of honey (Clapperton et al. 1989). The loss of honey and the cost of replacement bees make up a significant portion of the financial costs of *Vespula* wasps to New Zealand.

We modelled a number of benefits to beekeepers should wasps be removed. These included the removal of all future wasp management costs, bee replacements following wasp attacks, and bee product losses both in hives currently destroyed or seriously affected and in all other hives that need to expend resources defending against wasp attacks. In addition, as a secondary effect, it was estimated that some of the savings in wasp management and replacement costs could be passed on through lower pollination charges for growers in the arable and horticultural sectors[5].

To investigate these benefits, we surveyed members of the National Beekeepers Association (NBA) over a period of 1 week from 25 May 2014 to 1 July 2014 and asked them seven questions aimed at examining the impact of wasps on apiculture. The survey and some of the results are provided in Appendix 1. In this survey, we asked about the numbers of hives lost to wasps, costs to protect hives from wasps such as extra travel and inspection, and any control costs of time and materials. One hundred and one beekeepers responded. Most of them provided responses to most questions.

5 This would occur over time and depend on how competitive the apiary services market was. If beekeepers had higher value uses for their hives than providing pollination services, then most of the savings from the removal of wasps would be retained by beekeepers.

### *Avoided cost of managing wasps*

Responses to the NBA survey suggested that wasp management costs vary widely depending on the circumstances of the individual beekeepers. Sixty percent of respondents had costs of less than $5/hive/year, but the remainder had higher costs—and those costs increased sharply, with 29% having costs ranging from $5/hive/year to $20/hive/year, and the remaining 11% having costs above $20/hive/year. When we spoke to several of the beekeepers about their estimates, their feedback reflected the pattern seen from survey respondents—beekeepers with more hives in pastoral and horticultural areas tended to have lower costs than those with hives in forestry and native bush areas.

Based on these findings, we estimated that the average annual cost to beekeepers of managing wasps was $5 per hive. This included the labour involved in locating and removing wasp nests, the transportation of hives away from wasp threats, and the return of the hives once the wasp threats had subsided, as well as equipment costs. Interventions to prevent wasps include management techniques and equipment such as aperture reductions which will reduce hive losses but also depress honey yield[6]. Therefore the $5 cost per hive is likely to be conservative.

In New Zealand, there was an average 6% increase in the total number of hives from 2008 to 2013 and a 7% increase between 30 June 2012 and 30 June 2013. Therefore, we assumed a growth rate of 5% per annum for hive numbers over the first 5 years (2015–2020), followed by static hive numbers thereafter[7]. The same growth assumptions were used in the other estimates of apiculture benefits from the removal of wasps outlined below.

### *Avoided cost of replacing bees and production losses*

The annual rate of severe damage or total loss of hives due to wasp predation in New Zealand has previously been estimated by Walton & Reid (1976) and Clapperton et al. (1989). Walton & Reid (1976) estimated that German wasps destroyed 1.9% of New Zealand beehives in the 1974/75 season and affected a further 4.9% of hives, while Clapperton et al. (1989) calculated that wasps totally destroyed or seriously affected 8.13% of hives in 1985/86 and 9.35% in 1986/87. Clapperton et al. (1989) believed that their figures may have been an overestimation of total hive damage, however, because they received a higher number of non-responses from beekeepers who did not have a wasp problem. They also noted that some of the damage attributed to wasps may have been caused by other factors.

Clapperton et al.'s (1989) study was carried out at a time when common wasps were spreading around New Zealand and had not yet become fully established. The authors noted that German wasps caused greater damage to beehives due to their behavioural and ecological characteristics, but that there were large populations of common wasps in newly colonised areas that appeared to be displacing German wasps to some extent. Therefore, they suggested that although lower numbers of German wasps may be an advantage to New Zealand apiculture, this advantage has essentially been negated by dense populations of common wasps. Today, both common and German wasps are widespread throughout New Zealand, with common wasps reaching their highest densities in honeydew beech forest, where they have largely displaced German wasps (DOC 2006).

The survey of NBA members asked 'On average over recent years what percentage of hives per year have you lost to wasps?' Eighty-five out of 101 respondents answered this question, with their estimates showing a significant amount of variation (Fig. 4).

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6 There is likely to be some degree of overlap between wasp and varroa apiculture management costs, e.g. varroa treatment visits can double up with wasp activity checks. Therefore, the removal of wasps is unlikely to change some cost drivers for beekeepers.

7 This is conservative compared with the 10% compound average growth rate of export honey value estimated for 2000 to 2010 in Coriolis (2012: 9), which focused on the increase in mānuka honey output. However, apiculture is also subject to serious biosecurity risks such as the bacterial disease European foulbrood and so, on balance, we believed that a cautious approach was warranted.

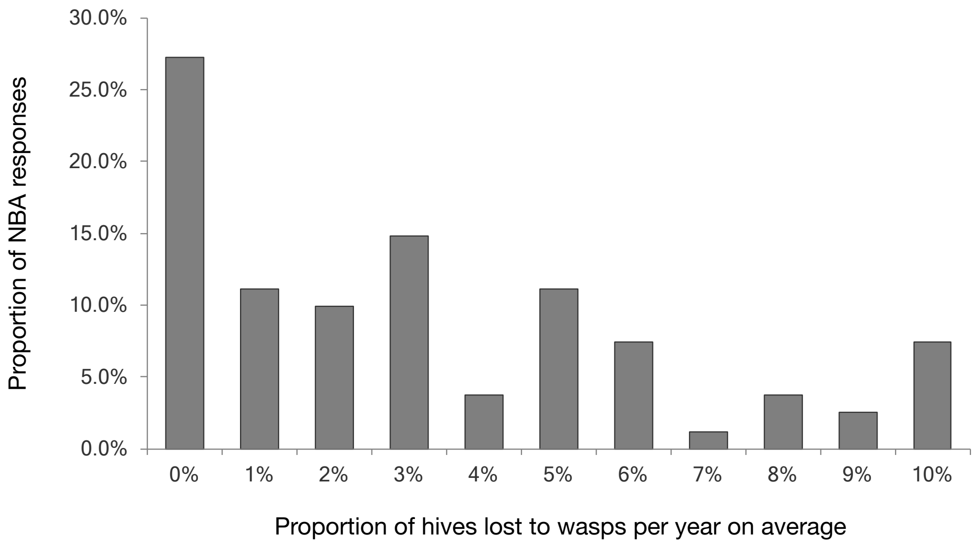


Figure 4. National Beekeepers Association survey responses on hives lost to wasps.
*Source: Sapere survey of NBA members.*

The weighted average of the annual hive losses to wasps as calculated from the survey was around 8%. Fourteen of the respondents did not provide a percentage of hives lost to wasps per year, but provided separate comments stating that their losses were 10% or higher (seven = 10–30%; seven = > 30%). However, some of these higher losses only related to the 2013/14 season, with lower numbers given for the annual average losses. If the losses above 30% are not included in the analysis, the average loss rate was 5%—and it is possible that even this is an overestimate due to non-responses from those unaffected by wasps.

Given the survey results and some likelihood that unaffected apiarists did not respond to the survey, we assumed a 5% rate of hive loss to *Vespula* wasps per annum as a national average. This is lower than Clapperton et al.'s (1989) estimates of 8.13% and 9.35%, but higher than Walton & Reid's (1976) estimates. This estimate will be subject to measurement error but provides a guide to possible wasp impacts.

The cost of bee replacements following wasp attacks was modelled as the value of a 1-kg package of bulk bees plus the price of a queen (i.e. $63[8]). In addition, it was assumed that these bees would need to be fed c. 25 kg of sugar to build them up to replace a destroyed or seriously affected hive, and so $27.50 per hive ($1.10/kg[9] × 25 kg) was added to the cost estimate for sugar. Beekeepers commented that recovery from wasp losses could be managed by splitting hives in preparation for losses rather than purchasing bees and a queen in bulk; however, hive splitting does involve some additional costs[10].

Half of the estimate of gross margin per destroyed or seriously affected hive was added to the cost estimate to cover the bee revenue lost in that year while the hive was being replaced or rebuilt following a wasp attack. Wasp damage is likely to affect a mix of the current season's and next season's revenue, depending on when the damage occurred during the season.

8 Source: MPI 2013 Hort~Apiculture_DATA RELEASE, Tab 'Table 6 Returns for Ap. Product'.

9 Source: MPI 2013 Hort~Apiculture_DATA RELEASE, Tab 'Table 7 Expenditure average sugar price per kg'.

10 The market price of replacement bees should reflect the cost of raising these bees until their sale plus a margin to make it worthwhile for apiarists. This price is therefore a proxy for the value of splitting hives, as selling the new hive is another option for apiarists.

Bee product losses as a result of wasps were estimated from the revenue per hive that is obtained from apiary products and services that wasps affect, such as honey, pollen, pollination and bees. The revenue per hive was estimated at $374, which was derived from MPI's 2013 apiculture monitoring programme[11]. This source also provided data on total production estimates, hive numbers, and export prices and volumes.

An average estimate of apiculture earnings before interest and tax (EBIT) was used to estimate the EBIT impact of loss per destroyed or seriously affected hive, and to provide a net view of estimated losses caused by wasps. A value of 29% (i.e. $109) was used, which was derived from MAF (2008)[12]. This could be a conservative view of current EBIT because the prices of key apiculture revenue items such as honey, pollen, pollination, beeswax and live bees have increased significantly since 2007/08. However, key cost items do not appear to have increased as much as revenues, which should improve the EBIT margin.

The estimates of revenue per hive ($374) and EBIT margin per hive ($109) were checked with an experienced beekeeper who believed that they were not unreasonable. The revenue estimate was higher than lower producing hives providing light amber honey, but well under higher producing hives providing mānuka (*Leptospermum scoparium*) or kānuka (*Kunzea ericoides*) honey (estimated at $250–$550 per hive per year).

### *Avoided costs of lower production from defending against wasps*

Even if hives are not destroyed by wasps, they may still be affected by them, as bees expend resources defending against wasp predation. The losses in apiculture products as a result of this defence will not be high, but these resources would be reallocated to food collection were wasps eradicated from the area, which would increase the production of bee products. Therefore, in our assessment, we also included the benefit of increased honey production should wasps be controlled.

Bees guarding the entrances to hives near Lake Rotoiti, Nelson Lakes National Park. Photo illustrates the efforts bee colonies will expend to repell wasps, which were the likely invaders here, as they were abundant at the site when the photo was taken. *Photo: Eric Edwards.*

Clapperton et al. (1989) found that wasps were the greatest nuisance in areas where beekeepers' bees were foraging on honeydew and were the least nuisance where bees were foraging on pasture only. They also found that wasps appeared to cause the most problems in hives that had been left for the winter, with wasps' autumn activity being the next worst period for beekeepers. The NBA survey and discussions with beekeepers corroborated these findings.

It was therefore expected that wasps would have the least impact where hives were situated in horticultural or arable areas. However, the NBA survey responses showed that losses of hives due to wasps tended to be higher (in the order of 10–20%) in areas near the upper South Island beech forests, and in less accessible country where mānuka and kānuka were a key food source for bees. Therefore, it could be inferred that surviving hives (i.e. those not destroyed) in these areas would also experience greater reductions in production. Furthermore, since mānuka honey from these areas commands higher prices per kilogram than clover-based honey (Coriolis 2012), these wasp impacts would have an even greater economical impact.

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[11] Source: MPI 2013 Hort~Apiculture_DATA RELEASE, Revenue per hive per year estimated at $374.

[12] MAF ceased their EBIT estimates after 2008 due to concerns about its efficacy and so EBIT has not been calculated for various apiary types since publication of this report.

Discussions with beekeepers indicated that the spread of the giant willow aphid (*Tuberolachnus salignus*) could worsen the impact of wasps on apiculture. This insect may provide a rich food source for wasps over areas that are currently not too badly affected by wasps, which could increase wasp populations and therefore increase apiculture losses.

In the absence of better information about apiculture product losses from hives that are not destroyed by wasps, we assumed that on average there would be a 5% improvement in the production of apiculture products across New Zealand compared with the present situation should wasps be removed. This estimate was made for the purpose of this study and was based on a view that wasps were likely to have an impact perhaps similar to the estimate of hive loss. However, further research into this effect would be useful for a more accurate estimate in the future.

### 3.1.2 Apiculture—honeydew value foregone

Table 2. Estimate of potential honeydew value foregone. *Source: Sapere and John Hellstrom.*

| KEY FACTORS | APICULTURE INCREASE IN HONEYDEW HONEY PRODUCTION KEY ASSUMPTIONS |
|---|---|
| Area | 29% of upper South Island beech forest honeydew could be foraged by bees |
| Bee range | Bees forage 4 km from their hives on the edge of the beech forest (Malone 2002) |
| Wasp harvest | Wasps currently harvest 50% of honeydew |
| Potential bee harvest | Bees harvest 25% of the honeydew that wasps currently take, which equals 12.5% of honeydew within their range or 3.6% of all honeydew |
| Honeydew production | Honeydew production in these forests is 3500–4500 kg/ha/year (Beggs 2001); therefore, an average of 4000 kg/ha/year was used |
| Honeydew to honey conversion | 61% of honeydew kg is converted to honey kg, including honey used to fuel bee foraging |
| Hive maintenance energy use | 65% of honey kg is used for honey bee colony maintenance (e.g. raising brood, wintering) |
| Existing production | Existing honeydew honey production is 500 tonnes; this was subtracted from the value |
| Value of honeydew honey | Honeydew honey is worth around $6.50/kg (MPI 2013) |
| EBIT margin | Net of estimated costs of production was calculated by applying an EBIT margin of 29% |

| TOTAL ANNUAL VALUE | TOTAL NPV 2015–2050 |
|---|---|
| $57.8m | $577.9m |

An estimate of the potential honeydew value foregone is presented in Table 2.

Red and black beech forests (*Fuscospora fuscus* and *F. solandri*, respectively) cover over 1 million hectares of New Zealand, mostly in the upper South Island (Beggs 2001; Fig. 5). They are home to scale insects that produce honeydew, which is a high-energy food source for native birds, such as kākā (*Nestor meridionalis*) , tūī (*Prosthemadera novaeseelandiae*) and bellbirds (*Anthornis melanura*) (Beggs 2001), as well as honey bees and other invertebrates.

Ever since their arrival in New Zealand, wasps have taken advantage of the beech forest honeydew to such an extent that, according to DOC (based on work by Thomas et al. 1990), wasp densities in South Island beech forests are the highest recorded anywhere on Earth (Daly 2014).

### *Value of honeydew*

The value of honeydew foregone today due to *Vespula* wasps could be characterised as an option value under the TEV approach, as it represents an option to benefit from the potential use of some portion of the honeydew resource that is currently a major food source for wasps. However, the honeydew also represents a non-use impact on the environment and biodiversity that provides bequest and existence value because, if wasps were removed, there would be significant flow-on benefits to birds and other fauna that live in these beech forests. These benefits would be valued highly by many people as biodiversity to leave to subsequent generations.

Black beech *Fuscospora solandri* honeydew at Lake Rotoiti.
*Photo: Eric Edwards.*

The suppression of wasps could also improve ecosystem services benefits to people because honeydew provides supporting services such as the continuous cycling of energy and materials necessary to support all living things (e.g. photosynthesis and nutrient cycling). It would also increase the availability of honeydew as a food source to support bird populations and honey bees. The removal of wasps could modify the decomposition subsystem in forests, by changing the quantity of honeydew falling on the ground, which would consequently change soil carbon sequestration and nutrient capital (Wardle et al. 2010).

### *Amount of honeydew accessible to bees*

Should wasps be eradicated from New Zealand, the area that bees could access would likely be significantly less than the estimated 1 million hectares of honeydew beech forest shown in Fig. 5 because access to many of these forests is limited to both apiarists and bees due to the topography, other land use purposes, and a lack of suitable roads and tracks. Therefore, we sought to explore what the potential apiculture development might be by making a variety of assumptions about bee foraging capabilities within the beech forests and access by beekeepers to the beech forest fringes.

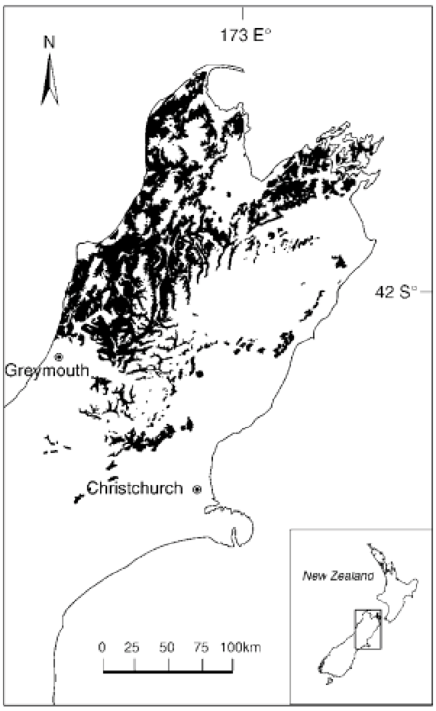


Figure 5. Honeydew beech forests in the upper South Island of New Zealand.
*Source: Beggs (2001).*

We assumed that bees could forage up to 4 km from their hives, with more intense foraging closer to their hives. This is comparable to the foraging distances reported by other authors—e.g. Winston (1987, cited in Malone 2002) reported that in forested regions, bees foraged at a median radius of 1.7 km from the hive and that most bees could be found within 6 km of their hive.

We then hypothesised that apiculture access limitations could be roughly approximated by examining the 1 million hectares of beech forest as a series of models represented by a circle or circles, as shown in Fig. 6[13]. In these models, the brown rings represent the average 4-km penetration of bees into the fringe of the forest; thus, honeydew in the green interior, which is > 4 km from the edge, was assumed to be inaccessible to bees.

[13] In the future, it may be possible to conduct a Geographical Information Systems (GIS) proximity analysis to better estimate the area of honeydew beech forest accessible to apiarists, based on Beggs' (2001) map of honeydew beech forest distribution (Fig. 5) (Peter Newsome, Landcare Research, pers. comm.). This could map the beech forests to access roads to provide an improved measure of forest that could be accessible. This approach was not followed in the present study due to time constraints.

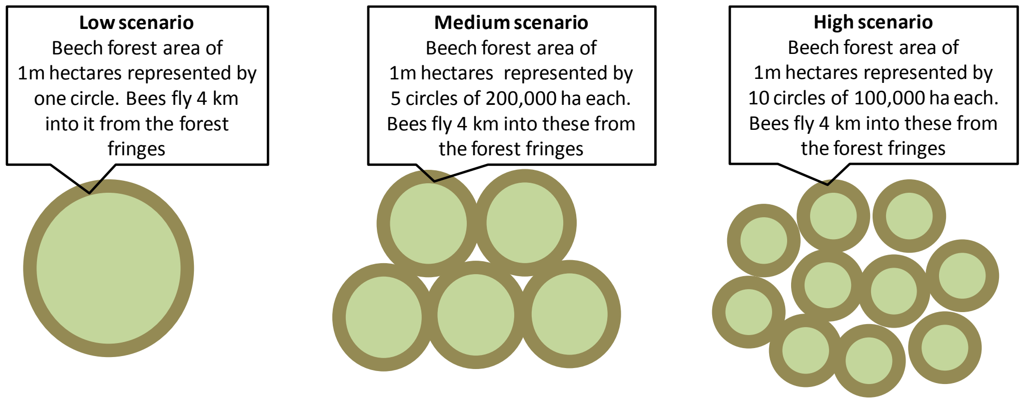


Figure 6. Conceptual models for assessing the honeydew production potential of upper South Island beech forests. *Source: Sapere analysis.*

From these models it can be seen that as the number of circles increases, the total area that is accessible to beekeepers and bees (brown) also increases. The low scenario, which is based on one circle, represents a conservative estimate of bee and beekeeper access to honeydew beech forests, whereas the high scenario, based on ten circles and with a total perimeter that is over three times greater, represents a more liberal estimate. It should be noted, however, that even the high scenario is very likely to fall well short of the total perimeter of all beech forests as shown in Fig. 5.

Based on these models, low, medium and high hypotheses of the potential foregone honey production from honeydew in these forests were tested. Under the medium scenario, it was assumed that beekeepers could place their bees to allow them to access 291 935 ha (29%) of the honeydew beech forest if they foraged 4 km into each of the five 200 000-ha circular areas. By contrast, under the low scenario, bees could forage over 136 735 ha (c. 13.7%) of the honeydew resource; and under the high scenario bees could access 398 137 ha (40%) of the beech forest area.

### *Amount of honeydew made available to bees*

According to Beggs (2001), wasps can take more than 90% of honeydew for around 5 months of the year; and similarly, a study by Moller & Tilley (1989) indicated that wasps almost totally monopolised the honeydew resource for 3–4 months of the year. However, Beggs et al. (2005) pointed out that both these studies were undertaken close to when wasps reached their population peak in New Zealand (around 1989) (Thomas et al. 1990, cited in Beggs et al. 2005). At this time, wasp nest densities of 23 nests per hectare were recorded (Barlow et al. 2002), compared with only 8 nests per hectare in the 2 years of Beggs et al.'s (2005) study. In a later study, Beggs et al. (2008) measured wasp densities across six sites over 19 years and found that although wasp densities have varied between years, there is no evidence for a long-term decline or increase.

We gathered varying opinions from apiarists, scientists and a wasp product exporter about the current level of wasp populations in New Zealand. The wasp product exporter believed that there were plenty of nests about and that wasp numbers were increasing again (Geoff Watts, pers. comm.). In addition, the Google trends tool showed that in January 2014 use of the term 'wasp' was at its highest level in the Google dataset for New Zealand. Therefore, based on the findings of Beggs (2001), Beggs et al. (2005) and Moller & Tilley (1989), more recent anecdotal evidence, and findings from the Google trends tool, we assumed that wasp numbers are currently at a lower level than at their peak, but that wasps still exploit 50% of honeydew production in these upper South Island beech forests.

It was also assumed that if wasps were removed, bees would harvest 25% of the 50% honeydew that was no longer taken by wasps in the areas in which bees could forage, i.e. would harvest an overall average of 12.5% of all available honeydew in the brown areas in Fig. 6). This means that under the medium scenario, bees would access 3.6%[14] of all available upper South Island beech forest honeydew, as we hypothesise that the majority is not accessible as it is more than 4 km from the forest fringes.

Beggs et al. (2005) estimated the dry weight of honeydew produced in beech forests at 3500–4500 kg per hectare per year[15]. Thus, in the low scenario we used a production rate of 3500 kg/ha/year of dry weight honeydew, with bees accessing 13.7% of the total area of beech forest area; in the medium scenario, we used 4000 kg/ha/year, with bees accessing 29% of the total area of beech forest; and in the high scenario we used 4500 kg/ha/year, with bees accessing 40% of the entire beech forest area.

### *Increased production of honey*

Beggs et al. (2005) found that honeydew consists of small amounts of glucose, and larger proportions of fructose, sucrose and oligosaccharides; the oligosaccharides were not identified, but are short-chain sugars. According to Grant & Beggs (1989), on average about 50% (range 38–64%) of honeydew consists of polysaccharides (Grant & Beggs 1989). Based on a web-based tool[16] and Grant & Beggs (1989), we selected an average conversion rate of honeydew to honey of 70%. The cost of bees foraging for this sugar source was calculated using a standard estimate of 128 grams per kilogram[17], reducing the yield to 61% of honeydew being converted into honey.

In addition, there are a number of maintenance costs that a honey bee colony must bear, including:

- The cost of raising a brood
- Metabolism of the colony's adult population
- Comb production
- Winter stores
- Cost of foraging for pollen
- Cost of raising drones
- Cost of raising new queens
- Cost of foraging for water

Various estimates are available for these costs, which are usually in the range of 60–80% of the total honey produced being used by the bees for these activities; however, no specific data for the production of honey from honeydew was found. The higher estimates were from northern hemisphere sites, where there were high over-wintering requirements. Therefore, since beech honeydew production is year round in New Zealand, and so over-wintering stores are not needed, we estimated that 65% of collected honey is used by the average hive, leaving 35% available for harvesting by apiarists.

To estimate the level of increase in the production of honeydew honey following the removal of wasps, we subtracted an estimate of the current production of honeydew honey (500 tonnes/year[18]) from the calculated level of production, which equalled 12 000 tonnes for the low scenario, 31 000 tonnes for the medium scenario and 47 000 tonnes for the high scenario.

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14 29% * 12.5% = 3.6%

15 Based on soluble carbon production by honeydew scale insects over 24 hours each month for 2 years. Honeydew production varied considerably between trees, types of beech tree, position of the measurement exclosures on the tree, and within and between years. The authors suggested that this variance was probably due to the population density of scale insects, with climate also playing a role.

16 www.beekeeping.com/goodies/conversions_bee.htm. Accessed June 2014.

17 www.urbanbees.co.nz/bee-facts

18 500 tonnes/year represents 4% of the 6-year moving average of total honey production in New Zealand, as calculated in the MPI 2013 apiculture monitoring programme (MPI 2013 Hort-Apiculture_DATA RELEASE). We believed that this might be a reasonable estimate as discussions with apiarists indicated that honeydew honey production was very challenging, with wasp predation being a major problem.

### *Value of honeydew honey*

Honeydew honey is worth around $6.50/kg (MPI 2013).

### *Economic gain*

To estimate the net potential earnings from this increase in New Zealand's apiculture industry, we applied the EBIT margin of 29%[19] to the honeydew honey revenues calculated. This estimate is likely to be conservative, as the EBIT margin which could be available from this additional honeydew honey production is likely to be higher in the absence of wasps because the price of dark honey, including honeydew honey, increased by around 100% between 2007/08 and 2012/13[20]. In addition, because the honeydew resource is available year round, the winter sugar feeding for bee maintenance (which is a major cost in the production of other types of honey) is very low.

The potential estimated increase in honeydew honey production ranged from $23m per annum in the low scenario, to $58m per annum in the medium scenario, to $89m per annum in the high scenario. This showed that there could be significant potential for the increased production of honeydew honey from apiculture in the upper South Island should wasps be removed.

The medium scenario was used to calculate the net present value of foregone honeydew honey production from 2015 to 2050 at around $578 million[21]. No increase in the price of honeydew honey was assumed over this period. It was also assumed that it takes 5 years to ramp up production to the medium scenario estimate of $58m per annum (nominal), as apiarists contract with landowners for access around the beech forests and build hive numbers.

## 3.1.3 Pollination benefits of wasp eradication

According to Federated Farmers, pollination from apiculture supports at least $4.5 billion per year in New Zealand's economy and underpins a further $12.5 billion of export revenue[22]. Major horticultural crops, pasture clovers, and some small seed (e.g. clover) and vegetable seed crops are dependent on honey bees. By contrast, viticulture and some other vegetable crops are much less reliant on bees, floriculture has little need of bee pollination, and grasses and cereals are generally wind-pollinated.

In some circumstances, the impacts of wasps on honey bees would potentially reduce the levels of pollination of these crops, thereby lowering crop set yield, size, quality and seed development to some extent. These impacts could be alleviated by increasing crop reliance on other methods of pollination, such as by using alternative pollinators or artificial methods. However, artificial methods, when used alone, are generally more costly and less effective, and thus rarely fully replace bee pollination; and research on the effectiveness of unmanaged insects to pollinate crops and management methods to maximise their effectiveness is still in its early stages[23]—and these unmanaged pollinators may also be impacted by wasp predation.

In the following sections, we estimate the economic gains that could be made in the arable, pastoral and horticultural sectors as a result of pollination benefits were wasps removed from New Zealand.

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[19] Sourced from MAF (2008). This price may be conservative as honeydew honey may command more of a premium. However, we have used this lower value here because there would be a marked increase in the production of honey.

[20] Source: MAF (2008) and MPI 2013 Hort~Apiculture_DATA RELEASE.

[21] 36 years using an 8% discount rate.

[22] For horticulture, arable, pastoral and beekeeping : www.fedfarm.org.nz/advocacy/National-Policy/Bees-Issues.asp

[23] Plant and Food Research recently secured funding through a successful Ministry for Business Innovation and Employment bid for a project entitled 'Bee minus to bee plus and beyond: higher yields from smarter, growth-focused pollination systems'. This includes quantifying the role of individual pollinator species (including unmanaged species) and exploring management methods for increasing populations of unmanaged pollinators to optimise crop pollination. www.msi.govt.nz/assets/Get-Funded-Documents/2013-science-investment-round/Biological-results/Biological-Industries-Research-From-Bee-minus-to-Bee-Plus-and-Beyond.pdf (accessed 5 August 2014).

## *Arable*

Table 3. Arable gains in the absence of wasps. *Source: Sapere analysis.*

| WITHOUT WASPS THIS IS POSSIBLE | ARABLE SECTOR KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Increased pollination production | A 1.5% increase in pollination leads to a 0.5% increase in arable seed production | $0.5m | $5.6m |
| Lower pollination costs | Pollination charges for arable pollination fall by $5/hive (3–4%) due to lower costs for apiarists following the eradication of wasps | $0.2m | $2.3m |
| Total | | $0.7m | $7.9m |

In this study, we modelled the increase in yields and decreases in pollination charges for the arable sector that would result from the removal of wasps (see Table 3). These impacts were modelled for crops such as white clover, brassica seeds, fodder radish, phacelia, borage, chicory, lotus, red clover, seed multiplication areas, yarrow, lucerne and hybrid vegetables.

We assumed that wasps would likely cause some decrease in pollination by eating bees and causing them to defend their hives when they could otherwise be collecting pollen and nectar. Clapperton et al. (1989) found that wasps had lower impacts on bees in pasture-only areas and anecdotal evidence gathered from beekeepers suggested that this is still the case today. In line with the approach taken in MAF's (2000) varroa model, which posited reduced production as a result of varroa's negative impact on bees, a reverse effect of 1.5% more pollination was assumed in the absence of wasps. The impact on yields was relatively minor, at one-third of the effect on pollination or 0.5%. The total farm gate value for insect pollinated grain and seed is estimated at c. $96.3 million (Nick Pyke, Chief Executive Foundation for Arable Research (FAR), pers. comm. 17 June 2014); thus a 0.5% increase would equate to an annual arable seed production increase of $0.5m. This translates to a net present value gain of $5.6m over the period 2015–2050, assuming constant prices[24]. It is also possible that an increase in pollination could improve seed quality, but this was not factored in.

MAF's (2002) review of the varroa economic impact assessment recommended that the production effect of varroa be reduced to zero from an original level of a 5% decrease in pollination, which was associated with a 1.67% drop in production. This resulted from the view that treatment of hives for varroa had been more effective than expected in the 2000 assessment (MAF 2000) and that the role of wild hives in pollination was considered less important than originally assumed. However, the change estimated here involves the removal of wasps, which should result in a persistent improvement in pollination rather than a marginal one. Therefore, we believed that it was reasonable to retain some small impact on production arising from the removal of wasps because bees would suffer less predation and be able to focus on collecting pollen and nectar rather than defending their hives.

An increase in pollination following the removal of wasps would translate into reduced pollination charges to growers. MAF (2002) used modelling to show that pollination charges to growers in the arable and horticulture sectors would increase by 33% if the New Zealand Government did not intervene to control varroa. However, for the purposes of this study, we assumed a much lower reduction in pollination charges to growers following the removal of wasps, at around 3%, as a conservative estimate. This translates into a reduction of $5 per hive from the current pollination charge rate, which ranges from $150 to $195 for canola and small-seed crops such as carrots[25].

[24] An increase in production could cause a marginal fall in the price of crops where New Zealand is a major producer, depending on the elasticity of demand for these crops.

[25] Sourced from MPI's 2013 apiculture monitoring programme.

This saving would first appear as a marginal cost saving or higher profitability for apiarists, as wasp control costs would no longer be required. However, over time this reduction would flow through to growers through lower pollination charges, which would reduce cash flows to beekeepers but provide a benefit to arable farmers. The net effect of this would depend on the elasticity of demand and supply for pollination services. Due to a current lack of information on these net effects and the relatively small amounts that are involved, we have only included the benefit to arable farmers in our assessment, and so these estimates can only be described as indicative. We also have not included multiplier effects in this study, the inclusion of which would be likely to demonstrate some net benefit from the reduction in the costs of pollination as a result of the eradication of wasps. A more detailed study of these effects would be necessary to unravel the total effects on arable pollination services.

### *Pastoral*

Table 4. Pastoral sector gains in the absence of wasps. *Source: Sapere analysis.*

| WITHOUT WASPS THIS IS POSSIBLE | PASTORAL SECTOR KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Nitrogen fertiliser cost avoided | 2.5% increase in pollination reduces the use of nitrogen fertiliser per ha on farms | $33.8m | $324.4m |
| Clover cost avoided | Reduced need for clover reseeding on a 5-yearly basis | $28.2m | $280.3m |
| Total | | $62.0m | $604.7m |

Table 4 summarises the estimated economic benefits to the pastoral sector following the removal of wasps from New Zealand.

A significant amount of the pollination of clover and other legumes depends on bees (see Rattray 2005: 15–17, 38; FAR 2009: 20; Goodwin 2012: 99 & 100; Newstrom-Lloyd 2013), and bees are often particularly attracted to clover (FAR 2012: 28 & 29; Newstrom-Lloyd 2013: 413). The removal of wasps would result in greater survival of bees, which could lead to bees spending more time pollinating clover rather than defending their hives from wasp predation (Goodwin et al. 2006: 1), as well as larger bee colonies, resulting in more foraging bees (Goodwin 2012: 30 & 31). Therefore, we assumed that this, in turn, would lead to an increase over time in pasture clover content, as more clover seed would be available to germinate, particularly in autumn following dry conditions[26].

Clover improves pasture growth (through the fixation of atmospheric nitrogen) and quality (as it provides more nutritious feed than grass). Following the removal of wasps, there would be an increase in clover nitrogen fixation and clover growth, which could reduce the need for nitrogen fertiliser applications and the amount of clover reseeding required. Therefore, we modelled the value of eliminating wasps as a decrease in the need for nitrogen fertiliser applications and clover reseeding. To do this, we followed the approach taken in MAF's (2000) varroa economic impact assessment, which did not quantify changes in bee numbers due to varroa but instead sought to estimate directly the effects on this sector of changes in pollination. We did not attempt to quantify the value in increased nutrition for livestock that may also result from the removal of wasps[27].

[26] The flowering of white clover (*Trifolium repens*) is important for the production and building of buried hard seed reserves, helping to maintain it in pastures (see Rattray 2005: 81; FAR 2009: 8). In dry conditions, early flowering, free-seeding clovers help to maintain the sward; however, stolon development has been shown to be the major contributor to maintaining clover sward in some situations (FAR 2009: 38).

[27] For a list of studies that have estimated the total benefits of clover to New Zealand, see Rattray (2005: 17).

We assumed that the increase in clover benefits would occur over 6 years, with only 10% of the savings feeding through in 2015 and the rate of impact rising to 90% by 2019. We also assumed that removal of the predation of bees by wasps would result in a 2.5% increase in atmospheric nitrogen fixation by clover. This is consistent with the reduction in nitrogen fixation that was assumed for varroa in the MAF (2002) review of the varroa economic impact assessment[28], and so the impact of the removal of wasps was assumed to have a similar effect on bees as the onset of varroa, i.e. a small but definite effect. However, the removal of wasps was assumed to be permanent, whereas MAF's (2002) reassessment indicated that treatments for varroa were being more effective than originally predicted in 2000, as discussed in the Arable section above.

Based on the revalidated varroa model assumptions about clover nitrogen fixation[29], a 2.5% increase in pollination would result in an increase in the average annual nitrogen fixation of around 3 kg per hectare on dairy farms and 1 kg per hectare on sheep and beef farms. It was assumed that following the removal of wasps, nitrogen fertiliser applications could be reduced on all dairy farms and 75% of sheep and beef farms. These fertiliser treatments consist of urea (46% N) on dairy farms, and half urea and half diammonium phosphate (DAP; 18% N) on sheep and beef farms. Therefore, this implies reduced annual nitrogen fertiliser applications of 6.5 kg per hectare on dairy farms, and 2.2 kg per hectare on sheep and beef farms. The average cost of urea was estimated at $605/tonne, plus $35/tonne for cartage and $85/tonne for spreading; and the average cost of DAP was set at $773/tonne, plus $35/tonne for cartage and $60/tonne for spreading (Phil Journeaux, AgFirst, pers. comm.).

Increased pasture clover content would also reduce the need for clover reseeding. Therefore, for the purposes of this study, we assumed that reseeding once every 5 years would no longer be required[30]. The cost of clover seed was set at $14.00 per kg for dairy farms, and $11.50 per kg for sheep and beef farms[31].

### *Horticulture*

Table 5. Horticulture gains in the absence of wasps. *Source: Sapere analysis.*

| WITHOUT WASPS THIS IS POSSIBLE | HORTICULTURAL SECTOR KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Lower pollination costs | Pollination charges for horticultural pollination fall by $5/hive (3–4%) due to lower costs for apiarists following the eradication of wasps | $0.74m | $8.7m |

Table 5 summarises the estimated economic benefits to the horticultural sector following the removal of wasps from New Zealand.

Decreases in pollination charges that would result from the elimination of wasps were modelled for a range of important fruit and vegetable crops: kiwifruit, apples, pears (not Asian), peaches, apricots, plums, nectarines, cherries, oranges, grapefruit/goldfruit, lemons, mandarins, tangelos, strawberries, boysenberries, blackcurrants, blueberries, feijoas, tamarillos, passionfruit, persimmons, avocado, peas and squash. The current hive requirements of these crops were

[28] The MAF (2000) varroa model assumed a reduction of 5% in nitrogen fixation, while the MAF (2002) review halved this to 2.5%.

[29] Phil Journeaux (AgFirst) checked the 2000 'Overseer' nutrient balance model assumptions that under normal conditions nitrogen fixation by clover contributes 106 kg of N per hectare per annum on a Waikato dairy farm (given a pasture clover content of 17%), and 40 kg of N per hectare per annum on a King Country sheep and beef farm (given a pasture clover content of 8%) (Phil Journeaux, AgFirst, pers. comm. June 2014).

[30] This assumption takes the more conservative value from MAF's (2002) varroa model, in which summer moist farms would need extra clover sown once every 5 years. The varroa model assumption that summer dry farms would need to be reseeded each year was not used., as this distinction between farm types was based on the assessment that varroa would wipe out wild hives on which the summer dry farming clover pollination was more dependent.

[31] Source: Phil Journeaux, AgFirst, pers. comm.; and www.agriseeds.co.nz/

assumed to be the recommended numbers of beehives per hectare, as outlined in MAF (2000: 15, tables 1 & 2)[32].

Apiarists' pollination charges to growers currently range from around $60 to $120 for pipfruit, stonefruit and berryfruit, and $120 to $195 for kiwifruit[33]. Consistent with the approach taken for the arable sector above, we assumed that costs for apiarists would fall in the absence of wasps, as wasp management would no longer be necessary, and losses of bees, honey and larvae to wasp predation would cease. Some of the reduced cost of the supply of pollination services would be passed on to growers, which we estimated at a $5 reduction in pollination charges, representing a decrease of between 2.5% and 4%. This is significantly lower than the 33% increase in pollination charges assumed in MAF's (2000) varroa model.

This reduction in pollination charges would reduce cash flows to beekeepers but provide a benefit to arable farmers. The net effect of this is currently unknown, but would depend on the elasticity of demand and supply for pollination services for horticultural crops[34].

In this study, we adopted the approach used in MAF's (2002) review of the varroa economic impact assessment, whereby the direct impact of the removal of wasps on the pollination of horticultural crops was not included. The reductions in crop yields modelled in the varroa work stemmed from the predicted effects of varroa on managed, hobbyist and feral hives. However, on reflection, MAF (2002) concluded that varroa was unlikely to have significant effects on horticultural crop yields as growers would demand well-maintained, high-performance hives. In addition, observations in varroa-infested areas indicated good hive strength and no sign of declines in crop yields. Similarly, we suspect that if wasps were removed, there may be some improvement in pollination, but that the main effect would be changed costs for apiarists.

### 3.1.4 Viticulture

Approximately 35 000 hectares are planted in grapes in New Zealand, with about two-thirds of this production located in the Marlborough and Nelson regions (Aitken & Hewitt 2013: 6). Since there are high wasp numbers in relatively close proximity to the vineyards in these regions, it was considered that if wasps had any impacts on viticulture, these should be evident there. However, as a check on this approach, we also talked to viticulturalists in the Wairarapa and Otago regions, and to Dr Simon Hooker (Science and Research Director of New Zealand Winegrowers) to see whether *Vespula* wasps caused material problems for viticulturalists in other regions.

None of those contacted provided feedback that wasps were a significant problem in New Zealand. Although some minor problems were identified, such as the disturbance of nests by farm machinery, no one considered wasps to be an economic problem for their production. Wasp control costs on vineyards were also considered to be minimal—and it was noted that since viticulture is quite an intensive activity, nests close to vines are generally identified and removed while they are still small and easily managed. No one contacted considered that there was any significant fruit loss as a result of wasp infestation, which contrasts with the findings of some studies in Australia (Lefoe et al. 2001). Therefore, we have not included any benefits for viticulture from the removal of wasps (although it should be noted that a longer, more detailed study may identify some costs to this sector). Health benefits from the removal of wasps for vineyard workers have been captured in the estimates of health benefits (see section 3.2).

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[32] These numbers were revalidated with MPI in June 2014.

[33] Source: MPI 2013 apiculture monitoring programme, MPI 2013 Hort~Apiculture_DATA RELEASE, Table 6 Note 3. The lower prices are for hives delivered to depot sites, while upper end prices include delivery into the orchard and sugar for three to four 1-litre feeds to stimulate the bees to collect pollen.

[34] Since the net effects are unknown, these estimates can only be described as indicative. We also did not include multiplier effects in this study, which would be likely show some net benefit from the reduction in the costs of pollination as a result of the removal of wasps. As is the case with arable pollination services, a more detailed study of these effects would be necessary to unravel the total effects on horticultural pollination services.

### 3.1.5 Livestock and animal health

Table 6. Livestock and animal health costs as a result of wasp attacks. *Source: John Hellstrom interviews with veterinarians.*

| WITHOUT WASPS THESE ACTIVITIES CEASE | LIVESTOCK AND ANIMAL HEALTH KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Wasp injuries to livestock/pets | 750 veterinary clinics, each with 2 consultations per year at $70 per case | $0.1m | $1.2m |

Table 6 summarises the estimated economic impact of wasps on livestock and animal health in New Zealand.

Wasps have small but significant impacts on animals that are similar to those on people (see section 3.2). There are approximately 750 veterinary practices in New Zealand and, based on some informal sampling, it appears that on average they each treat about two cases of adverse reactions to wasp attacks in domestic and farmed animals each year. Average consultation and treatment fees were estimated at c. $70, giving an annual cost of c. $100,000. In addition, there are occasional deaths of both pets and livestock caused by wasp attacks; however, these appeared to be rare and so the costs were judged to be immaterial. Although reports from Israel indicate that wasps may cause problems that lead to mastitis in milking cows (Yeruham et al. 2002), discussions with veterinarians in New Zealand did not reveal a similar problem here. A longer, more detailed study may be able to identify more detailed costs in this sector, however.

### 3.1.6 Forestry

Table 7. Forestry costs as a result of wasps. *Source: Sapere analysis with data sourced from Andrew Karalus of Nelson Forests.*

| WITHOUT WASPS THESE ACTIVITIES CEASE | FORESTRY SECTOR KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Wasp management costs | Existing anaphylaxis training, wasp ER events and wasp poisoning activities will no longer occur / be required | $0.14m | $1.6m |

Table 7 summarises the estimated economic impact of wasps on the forestry sector in New Zealand.

To investigate the costs of wasps to the forestry sector, we interviewed a representative from Nelson Forests Ltd. He stated that wasps had been identified as a significant hazard in the company's forestry operations because of the risk of extreme allergic reaction and potential for anaphylactic shock causing life-threatening emergencies (Andrew Karalus, Nelson Forests, pers. comm.).

Nelson Forests provides training for at least two members of each of its forestry crews to ensure that they are able to diagnose and treat anaphylaxis. This training is updated every 2 years and involves a 2-hour course in groups of around ten people for approximately 150 people in total. The course costs, including the trainer and attendance costs, were estimated at $15,000 per year.

Over the last 20 years, Nelson Forests has had to respond to several emergencies that required treatment with adrenaline and/or emergency evacuation. This has cost the company $5,000 per incident in actual costs, but this was only c. 10% of the total costs of disruption of production and recovery from an incident. Thus, the total cost of each event was estimated at $50,000. Nelson Forests estimated that such an event occurred every 5 years, which would equate to around $10,000 per year.

In addition, Nelson Forests conducts wasp control in areas where it is aware that wasps are present, which costs in the order of $3,000–$5,000 per year.

Adding these costs together gives an annual financial cost of wasps of $28,000 to $30,000 per year for this company. Foresters from other parts of New Zealand were also interviewed to see whether the wasp problems encountered by Nelson Forests translated to other areas. It was found that although wasps were a nuisance, particularly near native forest blocks and lakes in the summer and autumn, the level of the wasp problem was much lower in other areas such as Hawke's Bay and the Bay of Plenty. In light of this, it was assumed, perhaps conservatively, that only forestry companies in the upper South Island in proximity to the beech forests suffered the sorts of costs seen by Nelson Forests as a result of wasps. Therefore, based on Nelson Forests' share of the planted area of forestry in the Nelson/Marlborough, Canterbury and West Coast regions (c. 20%), we estimated an annual cost of wasps to New Zealand of $137,000, which translates into a discounted cost of $1.6 million over the period from 2015 to 2050.

Due to time constraints, it was not possible to obtain from other foresters the same detailed level of information that we received from Nelson Forests. In the future, a more in-depth survey could be conducted, however.

Table 8. Health sector impacts by wasps. *Source: Sapere research, Ministry of Health (MoH) and Accident Compensation Corporation (ACC) data.*

| WITHOUT WASPS THESE ACTIVITIES CEASE | HEALTH SECTOR KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Doctors' visits for *Vespula* stings | Number of visits provided in Dymock (1994) extrapolated to 2013 and GP visit cost taken from PHARMAC | $0.1m | $1.2m |
| Short-stay hospital visits for *Vespula* stings | Based on Ministry of Health wasp hospitalisations 2012/13 × cost of short hospital stay | $0.003m | $0.04m |
| Longer-stay hospital visits for *Vespula* stings | Based on Ministry of Health wasp hospitalisations 2012/13 × cost of longer-term hospital stay | $0.02m | $0.3m |
| Deaths from anaphylaxis as a result of *Vespula* stings | Based on Ministry of Transport's Value of Statistical Life × estimated anaphylaxis death rates from *Vespula* | $0.7m | $8.6m |
| Active ACC claims involving wasps | Based on annual average of ACC claims involving wasps from 2008 to 2014 | $0.3m | $3.0m |
| Total | | $1.1m | $13.1m |

## 3.2 Human health

Table 8 summarises the estimated economic impacts of wasps on the health sector in New Zealand, which include minor impacts that require doctors' visits through to more serious impacts involving hospital stays or even death.

### *Cost of visits to GPs due to* Vespula *wasp stings*

We used the approach taken by Ward (2013) to estimate the cost of visits to general practitioners (GPs) as a result of wasp stings. A baseline number of people visiting GPs due to *Vespula* wasp stings in Auckland was obtained from Dymock et al. (1994). These estimates were then extrapolated to 2013 using population census data for Auckland and the whole of New Zealand for 1996 and 2013[35]. A cost of $65 was used for each visit to a GP[36]. The population of wasp sting

[35] The implicit assumption is that Auckland sting rates are comparable to sting rates across the whole of New Zealand.

[36] Taken from PHARMAC Cost resource manual: www.pharmac.health.nz/assets/pfpa-v2-1-cost-resource-manual.pdf

victims was then forecast using Statistics New Zealand's median population projections[37]. This gave a current estimate of the annual cost to New Zealand of visits to GPs for *Vespula* wasp stings of c. $97,000 and a discounted cost of these visits over the period to 2050 of $1.2 million.

Naturally, this approach had some weaknesses because it relied on a 20-year-old study that examined only 158 cases over two seasons. Furthermore, Dymock et al. (1994) noted that their study did not include after hours consultations and that stings suffered in recreational activities during holidays were likely to be underestimated. The seasonality of wasp populations, which are driven by weather conditions and food source availability, may also have skewed these findings. However, despite these issues, this study allowed us to extrapolate data to produce a preliminary estimate of today's numbers of visitors to GPs due to *Vespula* wasp stings and to then calculate an approximation of these costs.

### *Cost of hospitalisation due to wasp stings*

The Ministry of Health (MoH) searched their 2012/13 data on external cause code X23.2, which should be recorded when people are injured by wasps. It found that there were 65 hospitalisations where this code was used. Most of these hospitalisations were for short-stay visits to hospital emergency departments. However, 23 of these were longer-stay hospitalisations. These numbers were derated on the basis of Dymock et al.'s (1994) estimates of the proportion (43%) of *Vespula* stings to *Polistes* stings.

MoH noted that these statistics did not necessarily correspond to the reason for admission to hospital, although use of this code was supposed to indicate that the wasp injury influenced treatment. Therefore, it is possible that the MoH external cause code data understate the numbers examined or admitted due to wasp stings, as coding may not always be correct (this is discussed further in the following section). MoH also noted that people who were admitted multiple times (transfers, readmissions, multiple incidents) were counted each time, so not all of these might represent individual cases. It was not possible to compare these data across time due to changes in reporting.

The annual cost of visits to emergency departments (short stay costs) was estimated at $3,500 per year, with admission for longer stays costing $22,300 per year. The total discounted cost of both short stay and longer stay hospitalisation over the period to 2050 was estimated at $296,344.

### *Anaphylactic deaths as a result of wasp stings*

Cohen (1989, cited in Dymock et al. 1994) stated that the death of Pharaoh Menes in 2641 BC was probably the first recorded human fatality from a hymenopteran sting. It was also noted that some people who were stung by bees and wasps had hypersensitive reactions, ranging from large local swelling to sudden death from anaphylaxis.

Golden et al. (2006) tested the systemic reactions of stings from two wasp species, namely *V. maculifrons* and *V. germanica*, the latter of which is found in New Zealand. They found that systemic reactions to wasp stings occurred in 11% of trial patients stung by *V. germanica*, while severe reaction occurred in just under 3% of patients. By contrast, reactions were more severe in patients stung by *V. maculifrons*.

MoH was approached for data on deaths from wasp stings in New Zealand. It reported that this underlying cause of death was recorded for one death between 2000 and 2010. However, this rate seemed at the low end of the range of death rates from anaphylaxis observed in other studies—for example, Charpin et al. (1994) estimated that deaths from venom stings occur at a rate of 0.09–0.45 deaths per million people per year. These data are subject to similar difficulties as those noted above in the discussion of hospital admissions, as the reporting of such deaths will depend

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[37] www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP2011.aspx

on whether or not anaphylaxis to venom was determined as the triggering event, rather some other event such as cardiac arrest—hospital staff have a number of external cause codes to choose from and do not always select all appropriate codes.

Therefore, we obtained an estimate of the number of people who died due to anaphylactic reactions to *Vespula* wasp stings from the Pharmaceutical Management Agency's (PHARMAC's) work on adrenaline auto-injectors for first aid treatment of anaphylaxis (PHARMAC 2010). This work reviewed studies of the incidence of anaphylaxis, including a study by Low & Stables (2006), which estimated a death rate of 4.02 deaths per 4.4 million people per year (PHARMAC 2010: tables 2 & 8). For the purposes of this study, we halved this death rate in an attempt to count only those deaths expected from *Vespula* wasp venom-related anaphylaxis[38].

The Ministry of Transport's (MoT's) updated Value of Statistical Life (VoSL) (MoT 2013) was used to estimate the value of life lost through anaphylactic death due to wasp stings. This measure had risen to $3.85 million per fatality as at June 2013, following indexing to wage inflation. This rate was applied to calculate a human-cost for deaths from *Vespula* wasp stings, which was estimated at $733,000 per year. This represents one death from this cause approximately every 5 years. The discounted cost of these deaths over the period to 2050 was forecast at $8.6 million[39].

A representative from Allergy New Zealand pointed out that mortality from anaphylaxis can depend on a number of factors, including access to emergency treatment with intramuscular adrenaline and/or access to immunotherapy (desensitisation) in the population concerned (Penny Jorgenson, Allergy NZ, pers. comm. 5 June 2014). However, although there will likely be improved access to emergency treatment and immunotherapy in the future, it may still be appropriate to forecast continued mortality rates in the period to 2050 at the rates assumed in this report because susceptible individuals do not always react as expected to wasp stings (Golden et al. 2006).

### *Accident Compensation Corporation wasp claims*

The Accident Compensation Corporation (ACC) was approached for information on claims involving wasps. ACC did not have a specific code to identify 'wasp' incidents, but a search on free text matches to 'wasp' provided data on active claim costs involving wasps from 2008 to 2014. These costs ranged from a low of $165,326 in 2012 to a high of $330,022 in 2014. Therefore, the average cost of $254,450 over the 2008 to 2014 period was used to estimate the annual nominal costs of ACC wasp claims. This estimate was rolled forward to 2050 without adjustment for population growth or other factors to assess the potential costs of wasps between 2015 and 2050, which totalled c. $3 million.

It should be noted that ACC cautioned that there may be some inaccuracy in the data due to timing issues. Active claims generate a payment within the year, but claims would not necessarily have been lodged in the same period as the accidents occurred. Therefore, a claim might be active over many periods and could appear more than once in the data. Active claims also include all new claims in that period. Claims that only received bulk-funded hospital services were not included. There were some fatality claims, but because there were less than three of these it was not possible for ACC to provide details because this was below its limit for confidentiality.

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[38] Based on Dymock et al.'s (1994) estimate of the proportion of stings caused by *Vespula* v. *Polistes* wasps.

[39] For the purposes of this estimate, the value of the VoSL was not altered by inflation indexing.

## 3.3 Traffic accidents

Table 9. Traffic accident social costs caused by wasps.
*Source: Sapere and Ministry of Transport data.*

| WITHOUT WASPS THESE ACTIVITIES CEASE | TRAFFIC ACCIDENT KEY ASSUMPTIONS | ANNUAL VALUE | NPV 2015–2050 |
|---|---|---|---|
| Serious injury crashes | $826,000 per serious crash ($4,536,300 per fatal crash but none recorded in 2012 or 2013) | $1.1m | $12.9m |
| Minor injury crashes | $85,000 per minor crash | $0.3m | $3.5m |
| Total | | $1.4m | $16.4m |

Table 9 summarises the estimated economic impacts of wasps on New Zealand as a result of traffic accidents.

Wasps appear to cause some traffic accidents in New Zealand. These are particularly likely to occur in the summer time, when motorists are more likely to be driving their cars with their windows open, or when cars are often parked with the windows open and with a food source for wasps inside, following which people drive off unaware that there are wasps in their car.

MoT was approached for data on traffic accidents caused by wasps. It provided data for 2012 and 2013, which showed that wasps were the cause of one serious injury crash and two minor injury accidents in 2012, and three minor injury crashes in 2013[40]. We believe that caution is needed with these estimates, however, because there could be identification problems in these situations as well as possible post facto rationalisations. No accidents causing deaths were reported. However, MoT noted that wasps could have caused some fatal accidents but would not have been identified as the cause if the driver was the sole occupant of the vehicle.

The social cost of a road crash is defined by MoT as the total cost that occurs as a result of the road crash. In New Zealand, this includes the following:

- Loss of life and life quality
- Loss of output due to temporary incapacitation
- Medical costs
- Legal costs
- Vehicle damage costs

These social costs are either measurable directly or can be estimated in dollar terms. MoT's updated average social cost per vehicle crash was estimated at $4,536,300 per fatal crash[41], $473,600 per serious crash and $26,900 per minor crash. MoT explained that it adjusted this to $826,000 per reported serious crash and $85,000 per reported minor crash, after making an allowance for non-reported crashes (MoT 2013). For further information on how these values were calculated, refer to the appendix of MoT (2013).

For the purposes of this study, we used the above cost estimates that allowed for under-reporting. Since the data used were for 2 years only, this is likely to be only a rough indicator of the social cost of accidents caused by wasps. For example, one death in a vehicle crash would significantly increase the cost estimates because a crash causing death is nearly ten times the cost of a serious injury crash. In addition, wasp populations vary significantly between years due to influences such as weather and food availability, so 2012 and 2013 might not have been particularly

[40] It was not possible to extract usable data from earlier years. Note: The cause or possible cause of non-injury accidents was not recorded.

[41] This is higher than the VoSL used above in the analysis of death from Vespula wasp stings due to anaphylaxis because each crash can cause multiple injuries of varying severity.

representative of other years. No information was available on whether the crashes were caused by *Vespula* v. *Polistes* wasps, and so no adjustment was made for this. However, the cost of accidents caused by wasps and bees was averaged as a way of addressing potential species identification problems.

## 3.4 Regional councils and unitary authorities

Sapere attended the regional council and unitary authority Biosecurity Working Group meeting in Wellington on 22 May 2014 to explain this study. As a result of that meeting, a short survey was sent to members of this group, asking them if they could indicate their latest work under Section 72 of the Biosecurity Act 1993 and regional pest management plans (RPMPs) if these plans covered wasps. Members were also asked what their annual spend on wasp control was, and for any information they might have on the state and trend of public interest in wasps, including call centre inquiries and website hits about wasps. In addition, the impact on council operations was explored, e.g. environmental work or other pest control activities.

Regional councils and unitary authorities generally classify wasps as a restricted pest in their RPMPs. This means that wasps are either widespread or cause minimal environmental damage. Cost benefit analysis is done as part of the RPMPs and this usually determines that investment in the management of wasps is not appropriate. However, regional councils and unitary authorities do support landowner efforts to control wasps through the provision of advice and education, particularly around which products and contractors are available for wasp control.

Auckland Council noted that it was in the early stages of preparing its next RPMP. However, it stated that there are large differences in wasp abundance across the Auckland region and that the Waitakere City Council area has conspicuously higher rates of wasp complaints than other parts of the region. Auckland Council explained that its advisor who dealt with pest animals in West Auckland thought that the 2013/14 season had been considerably worse than usual, and estimated that he alone had spent a cumulative total of about 3 weeks' work controlling wasps over the peak season, with every second call he received in that time being about wasps.

Auckland Council also said that pest control contractors are commonly stung during the wasp season in the Waitakere Ranges and Hunua. It reported that projects such as Ark in the Park stop all baiting operations from February to April to prevent volunteers from being stung during this peak period. Researchers on a variety of projects (including, but not limited to, kauri dieback) are also often affected, as people are unable to undertake sampling due to wasps. In addition, anecdotal reports indicate that people do not want to go into the bush in West Auckland due to wasps. This could indicate that research into displaced recreation may be fruitful in this area (see section 3.5—Recreation and tourism below).

Wasps are included in Greater Wellington Regional Council's (GWRC's) RPMP for 2002–2022 (GWRC 2013), in the site-led pest management category programmes under 'Human Health'[42]. Because of this, land occupiers must destroy all wasp nests within their boundaries that are creating a human health hazard to affected parties. GWRC also explained that it prepares wasp reports annually[43], and monitors wasp nests found within the region and collates these data into its annual Wasp Nest Register. This information has been collected by the relevant territorial authorities (DOC and GWRC) for 23 years, and includes wasp nest type, frequency of occurrence, location and time of year. GWRC commented that it hoped that its monitoring of wasps on a regional basis would aid the effectiveness of its wasp biological control programme, and improve understanding of seasonal influences on the wasp population.

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42 www.gw.govt.nz/site-led-pest-animals (accessed 6 August 2014).

43 An example is available at www.gw.govt.nz/assets/council-reports/Report_PDFs/13.874.pdf

The trends in GWRC's Wasp Nest Register are shown in Fig. 7. From this it can be seen that wasp numbers appear to be trending downwards; however, the 2013/14 season has not yet been included in the series and has been notable for higher populations than usual (see above). These data may appear in GWRC's next wasp report.

The Google trends tool can be used to provide an index of how many searches were done on the term 'wasp' using the Google search engine over time (on a scale of 0–100). This showed that in January 2014, New Zealand Google searches on the term 'wasp' was at its highest level in the Google dataset, with an index value of 100. This might indicate that the 2013/14 wasp season saw very significant wasp populations relative to recent years[44]. It should be noted, however, that while it is likely that this trend could be linked to increases in wasp populations, it might not necessarily be indicative of an increase in wasp numbers, as other factors may also influence the observed trend.

It was not possible to collect data on costs for regional councils and unitary authorities from 9 out of 16 councils. The data that were collected did not indicate a high level of costs, but were incomplete and varied significantly between councils; therefore, it was not possible to extrapolate the data gathered. However, costs appeared to be in the order of $3,000 per annum for the larger councils, with the focus on supporting landowner efforts to control wasps through advice and education[45].

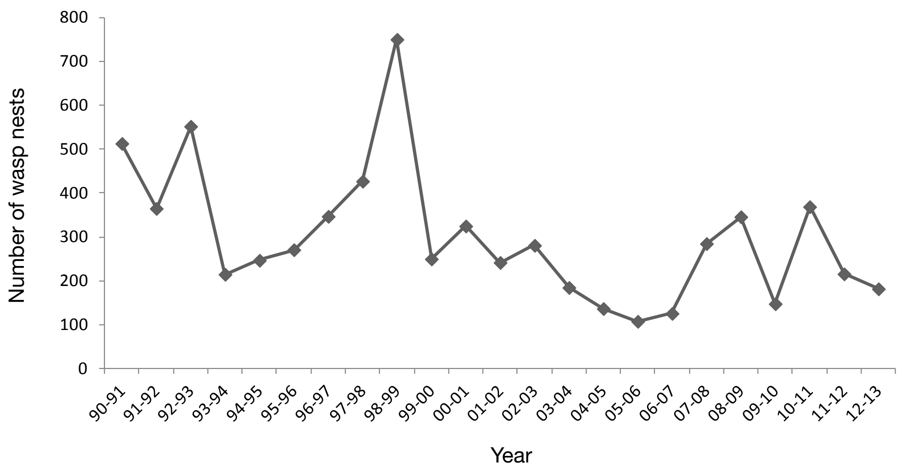


Figure 7. Greater Wellington Regional Council Wasp Nest Register data. *Source: Greater Wellington Regional Council.*

## 3.5 Recreation and tourism

The main impact of wasps on recreation and tourism is likely to be a result of the nuisance they can cause, which reduces enjoyment of these activities. Wasps impact on business (e.g. loss of opportunities for guided tourism), and reduce the quality of outdoor recreational activities such as tramping, hunting and picnicking (Kerr & Sharp 2008). To assess the degree of nuisance and reduced enjoyment it was necessary to:

- Put a value on recreation and tourism activities affected by wasps
- Measure how often and how severely wasps reduce that value
- Assess how many people are affected

[44] However, it could also be influenced by Google's share of the New Zealand search engine market.

[45] According to Giera & Bell (2009: 36, table 4.1) annual expenditure on pest animal management by regional councils was $18,112,000 (excl. GST), with an average of c. $1,207,000 over 15 councils. This means that councils are only spending a very small proportion of their total pest animal management budget on wasps.

### 3.5.1 Value of recreation and tourism activities affected by wasps

We reviewed a range of studies to examine the value of recreational activities in New Zealand.

Dalziel (2011) investigated the economic and social value of sport and recreation to New Zealand, in which he explained that economists use various techniques for estimating the benefit to people or their willingness-to-pay (WTP) for activities for which there is no market price. He cited several studies that have sought to estimate the value of outdoor recreation activities generally and for specific pursuits such as fishing and hunting, and noted that the benefits found in these studies were very large.

Dalziel (2011) used a 'revealed preference' method to estimate the direct benefits of involvement in sports and recreation. This approach sought to measure the opportunity cost of recreation time, comparing this time with an alternative of not taking time off for recreation but instead spending that time earning income. Dalziel (2011) estimated that an average adult aged between 25 and 34 spent c. 146 hours per year engaged in sport and recreation, or just over 18 working days (based on an 8-hour working day). Dalziel (2011) noted that people could choose to work rather than spend time in recreation. Therefore, the fact that they did not choose to do this showed that they received more value from recreation. They were revealing their preference for recreation but the value of their time spent employed provided a lower proxy for the value they placed on recreation. Dalziel (2011) used the statutory minimum wage as a conservative measure of the income that could have been earned had people worked instead of being involved in recreation[46]. At the time of the study, the minimum wage was $12.75 an hour, whereas it is currently $14.25 an hour.

Turner et al. (2011) carried out a similar study on the value of recreation in Whakarewarewa Forest. This study investigated the economic value that mountain bikers and walkers placed on recreation in this forest, and used the travel cost method to estimate the economic value or WTP of recreational use of the forest. From this, a median WTP per visit of $61 for walkers and $120 for mountain bikers was estimated. This represented the maximum additional cost a visitor to the forest would be willing to pay for vehicle and bike costs, and travel time, before they would decide not to visit, which can be used as a measure of the overall enjoyment a walker or mountain biker gains from visiting the forest.

Another useful study is that of Kaval & Yao (2007), who carried out a meta-analysis of 58 observations from 19 original studies dated between 1973 and 2002 to determine the non-market benefit of recreation. Their results showed that New Zealanders experienced a non-market benefit of $71/person/day for each 12-hour recreation day, which indicated that non-market benefits from outdoor recreation were over $5 billion per annum. This exceeded estimated market benefits of around $4 billion. Kaval & Yao (2007) provided a table of the non-market benefits per person per day of the top six activities in 2007 dollars (Table 10).

Table 10. Non-market recreation values of the top six activities in New Zealand. *Source: Kaval & Yao (2007: Table 2).*

| ACTIVITY NON-MARKET BENEFITS PER PERSON PER DAY | $NZ (2007) |
|---|---|
| Backpacking/tramping | $243.55 |
| Mountain climbing / rock climbing | $110.12 |
| Fishing | $81.77 |
| General recreation | $33.86 |
| Camping | $14.74 |
| Picnicking | $7.00 |

[46] Dalziel (2011) assumed that transport costs, clothing costs and equipment costs were similar for sport and recreation and employment.

### 3.5.2 Frequency and severity of wasp impacts

To estimate the frequency and severity of the disruption of recreation activities by wasps, we sent a survey to members of DOC's Recreation Advisory Forum (RAF) (see Appendix 2).

This was not an impartial survey of randomly selected New Zealanders and so will be subject to selection bias. Since this survey was intended as an information-gathering exercise, the questions were designed to gather as many responses as possible. To encourage members to respond, they were informed that the survey might be helpful in building support to address wasp issues via research into control methods, baits, genetics and wasp mites.

The potential respondents were first asked whether wasps affected their recreation choices. If they did, they were asked to answer the survey. In total, 135 responses were received.

Respondents were asked whether wasps had caused them to avoid recreational activities and how often this has happened in an average year. The responses of the 82 respondents to this question are shown in Fig. 8.

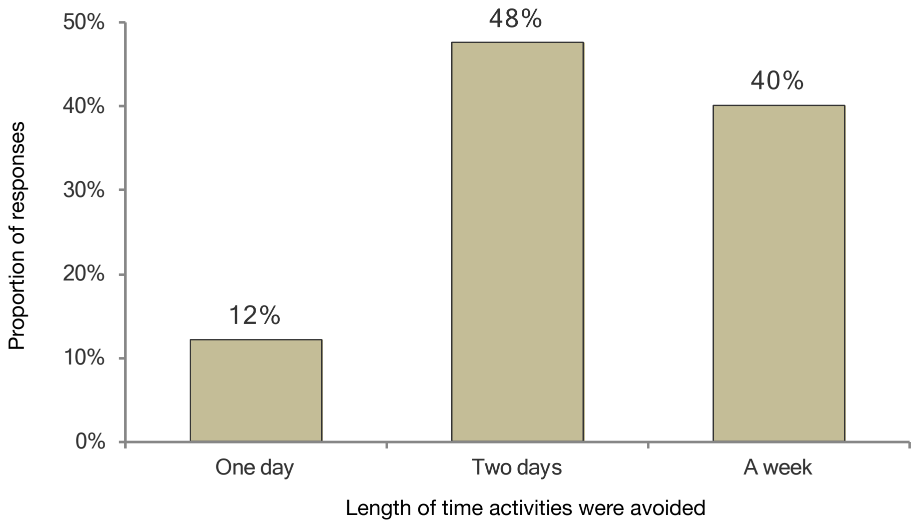


Figure 8. How often wasps cause people to avoid recreational activities.
*Source: Sapere survey of DOC's Recreation Advisory Forum members.*

Note: Sixteen respondents commented that wasps caused them to avoid recreational activities for longer periods, often between 1 and 3 months during late summer and early autumn.

Respondents were also asked to disclose the locations where their recreation choices had been affected by wasps. Nearly 70% of the 81 respondents who answered this question experienced problems with wasps in areas near the upper South Island beech forests[47] (Fig. 9). Respondents also commented on the numbers of people who were affected by wasps in their group and how they were affected. Some large groups were included where school camping groups, etc. were involved.

In an effort to ensure that people thought about the relative value of the impact of wasps on their plans, they were asked what they did as an alternative. In light of this, the respondents were then asked whether they would regard the effect of wasps on their plans as a minor, moderate or major inconvenience. The responses of the 87% of respondents who answered this question are shown in Fig. 10.

[47] Note: Because the survey was not randomised, respondent numbers will be driven directly by the places where problems with wasps were experienced.

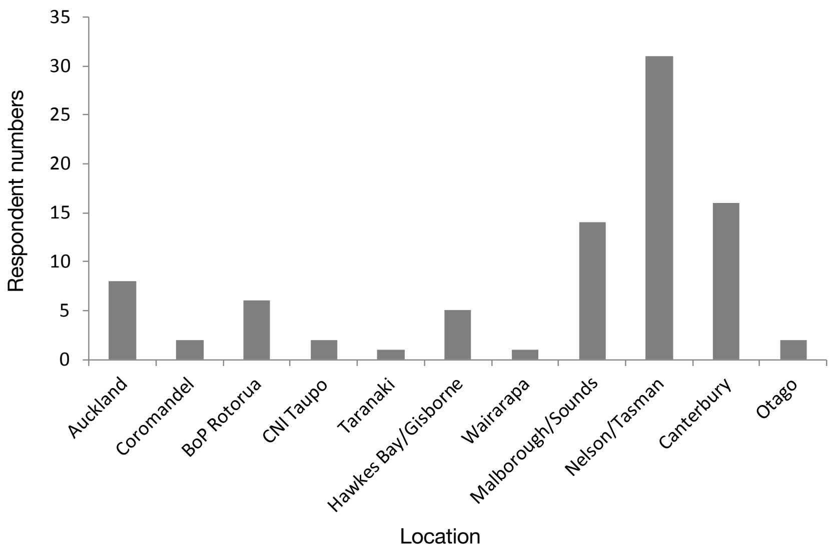


Figure 9. Places where respondents experienced problems with wasps. *Source: Sapere survey of DOC's Recreation Advisory Forum members.*

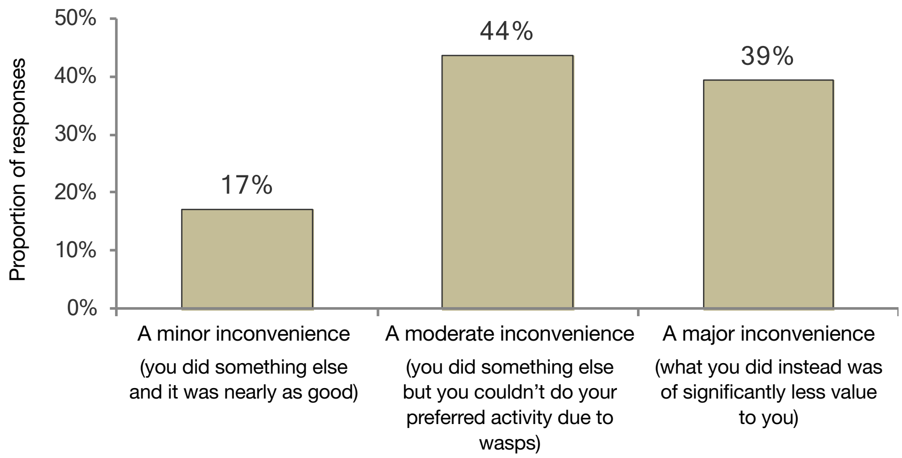


Figure 10. Level of inconvenience of wasps. *Source: Sapere survey of DOC's Recreation Advisory Forum members.*

### 3.5.3 Costs of wasps to tourism and recreation

The survey of RAF members drew 135 responses by 26 June 2014. As noted above, the respondents were not randomly selected. However, the survey did point to key geographic areas and likely recreational pursuits where wasps were deemed to be a problem.

The respondents whose recreational activities were most affected by wasps tended to be those who participated in recreational activities in areas where wasp populations can be high. The upper South Island beech forests were clearly a problem area, but other bush and forest areas also featured in the comments of respondents, such as the Waitakere Ranges and Waikaremoana. Activities that involved extensive access to bush or forested areas in these locations, such as tramping, mountain biking and hunting, were most affected by wasps.

On the basis of this, we thought that it might be possible to calculate a conservative estimate of the annual economic cost of wasps to tourism and recreation by focusing on activities in the upper South Island. This estimate could use the estimates of the value of recreation discussed in section 3.6.1 (indexed to today's dollars) for tramping, hunting and mountain biking, as well as information gathered from a larger, unbiased survey of people involved in these activities, including both New Zealanders and tourists.

As an example of what could be done, we generated some estimates based on the 96 survey respondents who answered the questions about:

- How many people were affected by wasps (including themselves and others in their group)
- Over what period of days they were affected
- What level of inconvenience they experienced

If a day of the respondents' time was taken and valued using Dalziel's (2011) revealed preference approach at today's minimum wage of $14.25 per hour, a day of tramping, mountain biking or hunting would be worth $114. This may be conservative because alternative activities for many people in employment are worth considerably more than the minimum wage, and people evidently prefer their recreation to employment or some other paid activity at the time they are tramping, mountain biking or hunting. In addition, many people might argue that they value a day on a track in the Richmond Ranges, for example, far more than a day in the office. This is also a low figure relative to Kaval & Yao's (2007) estimate of $243.55 in 2007 dollars for backpacking and tramping.

If it is assumed that a minor inconvenience is worth 25% of the $114 value of a recreational day, a moderate inconvenience is worth 50% and a major inconvenience is worth 75%, then the value of recreation lost to the 1162 people mentioned by the 96 respondents in the survey would be around $2m per annum. The largest single contributor to this value was a respondent who wanted to use the Nelson Lakes area—this respondent stated that wasps were a major inconvenience for some months to around 75 people because the desired outdoor activities were abandoned and the 'wasps cause the young people that I take to experience the outdoors to not want to ever return. The wasps often cause multiple stings and turn what would have been a totally positive outdoor experience into a negative one. They are a massive annoyance.'

Given a value of $2m per annum for this group of 96 respondents, it is quite possible that a randomly selected larger sample of upper South Island trampers, mountain bikers and hunters would provide a more accurate estimate of value of foregone recreation that could be significantly higher.

## 3.6 Biodiversity and the environment

As non-indigenous species that, on the whole, negatively affect New Zealand, wasps are considered invasive species. As shown in Fig. 2, wasps have both use and non-use impacts on biodiversity and the environment in New Zealand.

Wasps have upset three of the four main types of ecosystem services as defined in the Millennium Ecosystem Assessment (MEA 2005):

- Provisioning services—Through their impacts on food production
- Supporting services—Through their impacts on the cycling of nutrients
- Cultural services—Through their impacts on recreation and tourism, and biodiversity

The impacts of wasps on food production, and recreation and tourism were discussed in sections 3.1 and 3.5, respectively. Therefore, this section focuses on their impacts on nutrient cycling and biodiversity. This is followed by a discussion of the non-use impacts of wasps on the environment.

### 3.6.1 Nutrient cycling

Wasps have a negative effect on ecosystem supporting services, which arise from the continuous cycling of energy and materials necessary to support all living things, such as photosynthesis and nutrient cycling.

Wasps have a negative impact on bee populations which, in turn, reduces the pollination of clover (see section 3.1.3). Therefore, their removal would reduce the need to apply nitrogen and oversow with clover, which may reduce nitrogen leaching into freshwater, resulting in marginally less periphyton growth in New Zealand's waterways.

Wasps also remove a large amount of honeydew from South Island beech forests (see section 3.1.2), which is a crucial resource for the above-ground and probably also the below-ground systems (Beggs et al. 2005). Indeed, Beggs et al. (2005) concluded that scale insects have the potential to function as keystone species in these forests. In addition, Wardle et al. (2010) have shown that wasp populations greatly influence the storage of carbon, nitrogen and phosphorus in the soil humus, leading to increases in carbon sequestration. This highlights the whole-ecosystem impact of wasps.

### 3.6.2 Biodiversity

Ecosystems consist of a variety of indigenous and exotic flora and fauna coexisting with non-living physical resources such as soil and water. Biodiversity is often used as a measure of the health of an ecosystem, and attempts to measure biodiversity include indicators such as the number of species, population viability and distinctiveness (Kerr & Sharp 2008).

The negative impacts of wasps on biodiversity have been very well studied in New Zealand (Ward 2013). Indeed, Ward (2013) stated that Beggs' (2001) research was amongst the best on any invasive invertebrate in a natural ecosystem in the world.

Beggs (2001) showed that in the beech forests of the South Island, *Vespula* wasp populations reach levels well in excess of those found in their indigenous habitats due to the honeydew that is produced in these forests (see section 3.1.2). Thomas et al. (1990) demonstrated that in these forests, common wasps can reach approximate biomasses of 3761 g/ha at their peak, which, if averaged over the year, equates to 1097 g/ha—which is as great as, or greater than, the combined biomasses of birds (best estimate 206 g/ha), rodents (up to 914 g/ha in some years, but usually much lower) and stoats (*Mustela erminea*; up to 30 g/ha).

Beggs (2001) also found that wasps vie with other species for honeydew, and Elliott et al. (2010) demonstrated that bird species have experienced population declines over the last 30 years, some of which were probably caused by wasps. Harris (1991) found that wasps compete with birds and other animals for protein, and can consume up to 8 kg of invertebrates per hectare per year. In New Zealand, birds such as tūī, kākā and bellbird feed directly on honeydew, while other species such as the fantail (*Rhipidura fuliginosa*) and South Island tomtit (*Petroica macrocephala macrocephala*) compete with wasps for invertebrate foods. In the absence of wasps, bees would likely harvest only 3.6% of the honeydew in the upper South Island beech forests. Therefore, the rest of the energy value of the honeydew that is currently eaten by wasps would be available to other fauna and for ecosystem services such as carbon cycling.

Wasps also have impacts on invertebrate populations. Toft & Rees (1998) found that higher common wasp populations were correlated with lower garden orb web spider (*Eriophora pustulosa*) populations in beech forest habitats, and concluded that decades of wasp predation may have eliminated the most susceptible invertebrates. Beggs & Rees (1999, cited in Bashford 2001) showed that larger lepidopteran larvae were very vulnerable to wasps, with some so vulnerable that very few larvae survived into adulthood when wasps were at their population zenith.

Wasps also negatively affect other habitats, such as urban and rural gardens. For example, members of the Moths and Butterflies of New Zealand Trust try to encourage monarch butterflies (*Denaus plexipus*) in gardens and believe that *Vespula* wasps are important predators of their caterpillars. In fact, both *Vespula* and *Polistes* wasps eat monarch caterpillars and can have a major impact on caterpillar survival[48].

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[48] www.radionz.co.nz/national/programmes/ourchangingworld/20140508

### 3.6.3 Non-use impacts

To determine non-use impacts of wasps on the environment and biodiversity, the TEV approach includes bequest and existence values. However, these are generally challenging to estimate.

Kerr & Sharp (2008) conducted a choice experiment to estimate community preferences and values of the impact of wasps on indigenous species in the South Island. This focussed on changes in welfare caused by wasps, and how this changed the flow of services from the natural environment and indigenous biodiversity. They explored the attributes of the beech forest ecosystem with and without wasps, and asked people living in the South Island to choose their single preferred state, to reveal preferences about the outcomes of wasp management in Nelson Lakes National Park. The statuses of birds and insects were used as attributes to value the ecological effects of wasps, and value was revealed via a monetary attribute of 'cost to your household each year for the next five years'. This was presented as being paid via household rates levied to fund wasp management at rates of $0, $25, $50 or $100. Preferences were for attributes such as fewer wasp stings, more birds, more insects and lower costs. Kerr & Sharp's (2008) survey involved educating participants about wasp distribution, impacts and control. They noted that their values would not therefore represent values held by the general population who may have much less understanding of wasp impacts or their management.

Kerr & Sharp (2008) found that the surveyed community was willing to spend large amounts of money to protect and enhance bird and insect populations at Lake Rotoiti (Table 11). For example, wasp control that halted the decline in insect numbers was worth c. $150 per year to the average household in their survey, which was estimated to be worth c. $625 to the average household over 5 years. Summing this across approximately 300 000 households in the South Island yielded a total present value benefit of $195 million.

Table 11. Kerr & Sharp's (2008) choice modelling results.

| OUTCOME | MEAN ANNUAL VALUE PER HOUSEHOLD | PV @ 10% OVER 5 YEARS | AGGREGATE OVER 300 000 HOUSEHOLDS |
|---|---|---|---|
| Probability of stings increases by 10% | –$60 | –$250 | –$75m |
| Few birds | –$300 | –$1,250 | –$375m |
| Plentiful birds | $120 | $500 | $150m |
| Few insects | –$150 | –$625 | –$195m |
| Plentiful insects | $90 | $375 | $113m |

These findings suggest that New Zealanders value both recreation and the existence value of a biodiverse natural environment very highly, and it could be argued that Kerr & Sharp (2008) probably captured not only a use value of recreation, but also a portion of the bequest and existence value.

## 3.7 Benefits of wasps

Wasps not only have negative impacts on the environment and New Zealand's economy, but also bring some benefits. To examine some of these benefits, we interviewed Geoff Watts, a Christchurch-based exporter of wasp larvae and venom. Geoff exports wasp comb to Japan, where the larvae/pupae are eaten, and also exports freshly killed wasps to the USA, where their venom is used to treat anaphylaxis. This benefit was not quantified, but it was understood that this export trade has declined in recent years due to less favourable exchange rates.

Wasps also generate passive revenue through the sale of chemicals to control them. We interviewed a variety of pest control companies, from which it was determined that residential sales of wasp control products generate around $1 million per annum. This sums to around $11.7 million discounted at 8% from 2015 to 2050. It was not possible to estimate sales to commercial pest control firms.

The removal of wasps would affect all of these companies. Those companies that could produce an effective removal product (should any removal involve chemical baits) could increase sales, but those producing other products could see their sales cease.

Great white butterfly Pieris brassicae caterpillars on honesty Lunaria annua. *Photo: Richard Toft.*

Wasps may also have some ecological benefits. For example, they may play a role in pollination, or in controlling other pest insects such as flies, aphids or great white butterfly (*Pieris brassicae*) caterpillars. However, although various studies have provided useful information on wasp diets in scrubland pasture habitats (e.g. Harris & Oliver 1993; Harris 1996), they have not provided sufficient information to draw conclusions about any benefits of wasp predation across New Zealand. It is certainly possible that they could have some unrecognised benefits in pest insect control that would be removed were they effectively controlled, however.

# 4. Overall impacts and sensitivity analyses

## 4.1 Annual impacts

A breakdown of the costs of the impacts of *Vespula* wasps on New Zealand that were identified in section 3 is provided in Fig. 11. The direct use impacts of wasps were quantified at $75 million per annum. This is the sum of all of the costs shown in Fig. 11 except the 'forgone honeydew honey production' column on the far right-hand side. This latter column represents the significant option value for apiculture development around the upper South Island beech forests if wasps could be removed and totalled $58 million per annum. Therefore, the total quantifiable annual impact of wasps on New Zealand was estimated at $133 million.

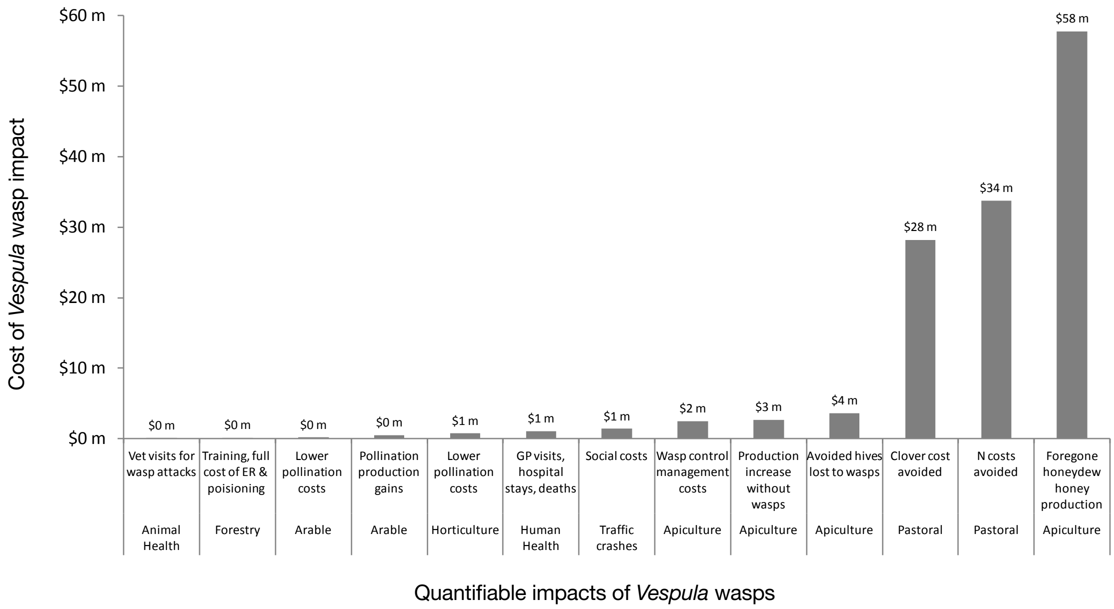


Figure 11. Annual quantifiable impacts of *Vespula* wasps on New Zealand. *Source: Sapere analysis.*

## 4.2 Net present value of impacts

A breakdown of the NPV of impacts of *Vespula* wasps on New Zealand that were identified in section 3 is provided in Fig. 12. The NPV of direct use impacts was estimated at $772 million from 2015 to 2050, while the option value for apiculture development around the upper South Island beech forests was estimated at an NPV of $578 million over the same period (Fig. 12). This gives a total NPV impact of $1,350 million.

## 4.3 Sensitivity analysis

There are some real uncertainties around the above estimates of the quantifiable costs of wasps to New Zealand as discussed in section 3, and it is quite common for the net effects arising from a given study to be overly optimistic. However, these potential biases can be investigated by testing which key factors have the largest effect on the values estimated.

The effect of such uncertainty on the study objectives is termed the 'risk', and this can be calculated by multiplying the probability of the estimate being true by the dollar value of the predicted harm or gain. Sometimes it is very difficult to assess risks, as many factors may not

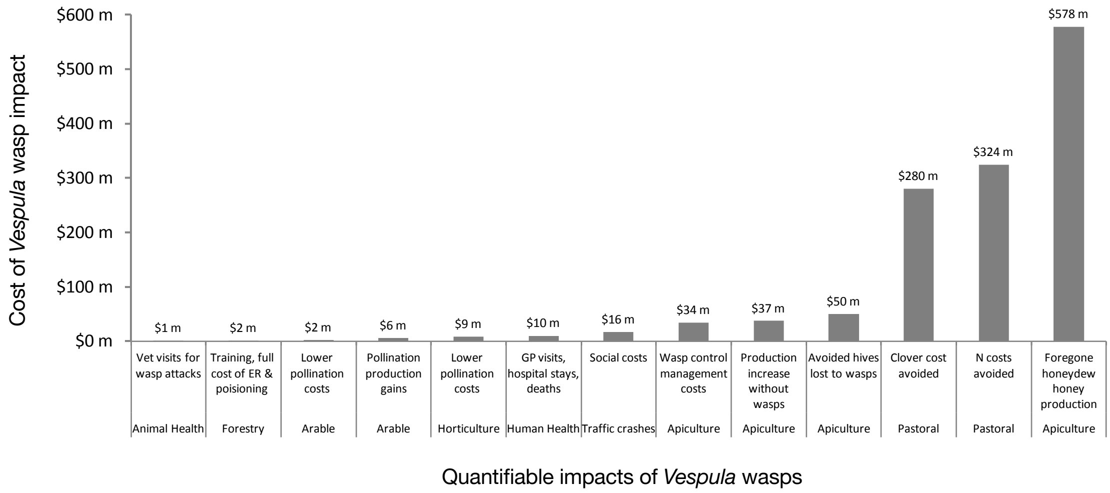


Figure 12. Net present value of quantifiable impacts of *Vespula* wasps on New Zealand. *Source: Sapere analysis.*

have easily quantifiable probabilities. Equally, risks may not be subject to standard models in which the probability of an event occurring centres on the average, while outlying events become increasingly rare at an increasing rate. For example, although physical data, such as population size or weight, generally follow a bell curve, social data often do not, as they are subject to high-profile, hard-to-predict or rare events.

In this study, we estimated the costs that would be avoided and the opportunities that could be gained if *Vespula* wasps were removed from New Zealand. The risks around these estimates are likely to be irregular and may include high-impact events that are not always of low probability, such as a wasp causing multiple traffic fatalities. In such circumstances, it can be helpful to conduct sensitivity testing based on the best and worst outcomes of these key factors.

In the following sections, some of the more significant impacts for which values were estimated in this study have been sensitivity tested. With the exception of the discount rate (section 4.3.1), the focus is on more conservative assumptions in order to probe some of the key estimates. It should therefore be noted that higher values than those estimated might also be possible.

### 4.3.1 Social discount rate

A discount rate of 8% was used throughout this study. If a lower discount rate of 5% was used instead, the estimated total quantified value from removing wasps in the period to 2050 would increase from $1,350 million to $1,990 million. Use of a lower discount rate could be argued as a social rate of time preference, which would give greater weight to returns expected into the future. However, since most of the returns quantified would provide a commercial return in a market place where other investments are also possible, e.g. apiculture and agriculture, a commercial discount rate is probably more appropriate.

### 4.3.2 Lower value for honeydew honey production foregone

The option value of honeydew foregone today due to *Vespula* wasps was the largest single value estimated. More conservative assumptions could be used to calculate the value of this, such that:

- Apiarists can only access beech forest shown in the map in Fig. 5 commensurate with the perimeter of a single circle as shown in Fig. 6; and
- The production of honeydew is at the low end of the range estimated by Beggs et al. (2005), at 3500 kg/ha/year of dry weight.

Based on these assumptions, the annual value estimate would decrease from $58 million to $23 million and the NPV from 2015 to 2050 would decrease from $578 million to $231 million.

This represents a marked reduction in value but demonstrates that the option value would still be very significant even with these more conservative assumptions.

### 4.3.3 Lower nitrogen fixation benefits

If wasps were assumed to have a lower impact on bee pollination, the 2.5% increase in nitrogen fixation following their removal that was assumed in this study could be halved. This would flow through to a lower level of saved annual nitrogen fixation of 1.5 kg/ha/year on dairy farms, and 0.5 kg/ha/year on sheep and beef farms. This, in turn, would reduce the value of nitrogen fertiliser saved from the current estimated level of $34 million to $17 million per year; and the NPV of saved nitrogen fertiliser from 2015 to 2050 would fall from $324 million to $162 million.

These values remain material even if these more conservative assumptions were used. It is also notable that this estimate of annual savings of $17 million is very modest compared with Federated Farmers' estimates that pollination from apiculture contributes at least $4.5 billion annually to New Zealand's economy and underpins a further $12.5 billion of export revenue[49] sectors.

### 4.3.4 Clover cost avoided

If wasps were assumed to have a lower impact on bee pollination, the savings from avoiding the need to carry out 5-yearly oversowing with clover would also reduce. The value of this would fall from $28 million to $14 million per year, while the NPV from 2015 to 2050 would decrease from $280 million to $140 million

### 4.3.5 Fewer hives lost to wasps

If our estimate of 5% of hives lost to wasps per annum were reduced to 3%, the annual value of costs avoided would fall from $4 million to $2 million, while the NPV from 2015 to 2050 would fall from $50 million to $30 million.

### 4.3.6 Conclusion

If all of the lower estimates outlined above were used to calculate the cost of wasps to New Zealand at an 8% discount rate, the total net present cost of wasps would be $681 million[50]. If a 5% discount rate were used instead, this would increase the total net present cost of wasps to close to $2 billion.

These estimates do not consider the non-use impacts of wasps on the environment and biodiversity, or their indirect impacts on tourism and recreation. If these were taken into account, as well as other as yet unquantified benefits, it is very likely that the net economic impact of wasps on New Zealand in the period to 2050 would range somewhere between $700m and $2 billion or more, with this report's point estimate being $1,350 million.

[49] Horticulture, arable, pastoral and beekeeping: www.fedfarm.org.nz/advocacy/National-Policy/Bees-Issues.asp

[50] This figure includes those value estimates that were not subjected to sensitivity testing at the values estimated for them earlier in the report. The total of these factors is an NPV of $118 million, which represents 17% of the total more conservative estimate of $681 million.

# 5. Acknowledgements

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# Appendix 1

## Survey of National Beekeepers Association members

### A1.1 Survey questions

Do wasps affect your apiary? We'd appreciate your views on the impact of wasps on NZ apiculture. This survey may be helpful in building support to address wasps via research into control methods, baits, genetics, wasp mites.

Participating in this survey is anonymous and confidential. We would appreciate receiving responses before noon on Monday 30th of June 2014. If you have any questions about this survey, please contact Peter MacIntyre from Sapere Research, ph 06 874 2421, or email pmacintyre@srgexpert.com

**1. In which region do you keep most of your hives?**

- [ ] Northland
- [ ] Auckland
- [ ] Waikato
- [ ] Bay of Plenty
- [ ] Gisborne
- [ ] Hawkes Bay
- [ ] Taranaki
- [ ] Central Plateau
- [ ] Wanganui
- [ ] Manawatu
- [ ] Horowhenua & Kapiti Coast
- [ ] Wellington
- [ ] Wairarapa
- [ ] Malborough
- [ ] Nelson & Tasman
- [ ] West Coast
- [ ] Canterbury
- [ ] Otago
- [ ] Southland

**2. Are your hives situated in areas which are primarily used for**

- [ ] Horticulture
- [ ] Arable farming
- [ ] Pastoral farming
- [ ] Forestry
- [ ] National parks and forest parks

Other (please specify)

**3. How many hives do you have?**

**4. On average over recent years what percentage of hives per year have you lost to wasps?**

- ◯ 0%
- ◯ 1%
- ◯ 2%
- ◯ 3%
- ◯ 4%
- ◯ 5%
- ◯ 6%
- ◯ 7%
- ◯ 8%
- ◯ 9%
- ◯ 10%

Other (please specify)

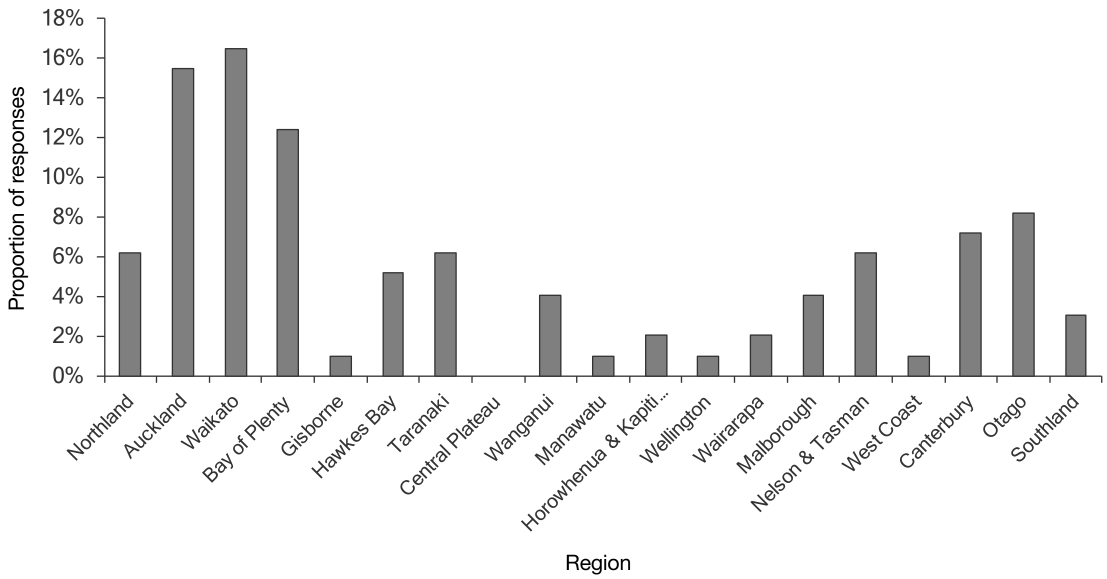
**5. On average over recent years how much honey (kg) per year do you think you have lost to wasps?**

**6. What do you estimate it costs you each year to protect your hives from wasps? e.g. extra travel and inspection and any control costs of time and materials.**

**7. Do you have any other comments on the cost of wasps for apiculture in NZ?**

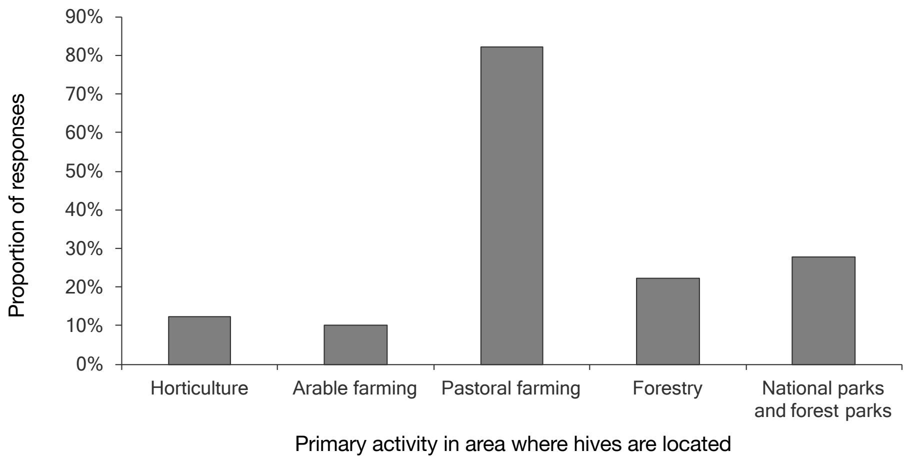
## A1.2 Survey responses

### *Question 1*




### *Question 2*

(Note: Percentages do not add up to 100% as respondents often had hives in multiple areas.)




### *Question 3*

This question required a written answer, so it was not possible to produce a graph for it.

### *Question 4*

See Fig. 4, section 3.1.1.

### *Questions 5–7*

These questions required written answers, so it was not possible to produce graphs for them.

# Appendix 2

## Survey of National Recreation Advisory Forum members

(Note: Membership of the National Recreation Advisory Forum includes recreation industries and recreation group leaders.)

Do wasps affect your recreation choices? If yes, we'd appreciate your feedback by answering this short survey. This survey may be helpful in building support to address wasps via research into control methods, baits, genetics, wasp mites.

Participating in this survey is anonymous and confidential. If you have any questions about this survey, please contact Peter MacIntyre from Sapere Research, ph 06 874 2421, or email pmacintyre@srgexpert.com

If wasps have caused you to avoid recreational activities...

**1. How often has this happened in an average year?**

- One day
- Two days
- A week

Other duration

**2. Where has this happened?**

**3. How many people has this affected?**

**4. Given wasps caused you to change your recreation plans, what did you do instead?**

**5. In light of what you did instead, would you regard the effect of wasps on your plans as**

- A minor inconvenience (you did something else and it was nearly as good)
- A moderate inconvenience (you did something else but you couldn't do your preferred activity due to wasps)
- A major inconvenience (what you did instead was of significantly less value to you)

Other (please specify)

**6. Do you, as part of your recreational activities, carry first aid for wasp stings or anaphylaxis (Anaphylaxis is the most severe form of allergic reaction, it can affect many parts of the body, cause breathing difficulties, and/or sudden drop in blood pressure)?**

- Yes
- No

**7. If you have other comments or additional ideas on how wasps may affect your recreational activities we would welcome them**

New Zealand Government