Economic assessment of BMSB management

Effectiveness of a biological control agent for Brown Marmorated Stink Bug (*Halyomorpha Halys*)

Final NZIER report to Horticulture New Zealand

3 August 2017

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Authorship

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Key points

Objective

This report provides an indicative estimate of the costs and benefits to the horticultural growing and processing industries of introducing the Samurai Wasp into New Zealand as a bio-control agent (BCA) to combat the Brown Marmorated Stink Bug (BMSB). Our focus is on preserving horticultural production and limiting the negative effects from BMSB.

Context

BMSB is an agricultural pest originating from in Asia, which feeds on fruit trees, field crops and woody ornamentals. It has worked its way to Europe and the US and caused damage to crops and infested houses, causing a public nuisance because of its smell and damage to residential gardens and commercial crops.

It has not yet been found in New Zealand, but could potentially arrive through a broad range of pathways into the country, including on imported goods and travellers' personal effects. There are an increased number of detections of BMSB at the New Zealand border.[1] It has now reportedly been detected in Chile, the first known example of it surviving in the Southern Hemisphere after travelling from the Northern Hemisphere.

This report examines the wider costs and benefits for the horticulture sector of different responses should BMSB arrive and become established. It complements and uses the same input data as a companion report on the economic impacts of BMSB, which uses computable general equilibrium (CGE) modelling to estimate the impacts across the economy should the bug become established here.

The CGE modelling paints a scenario of the BMSB's arrival in New Zealand in 2018, spreading across the country following a sigmoid curve of diffusion over the first ten years. Specific impacts on production are identified for pipfruit, grapes, kiwifruit and other fruits, and for vegetables and live plants and seeds.

The modelling projects the outputs of the potentially affected industries in the absence of the BMSB, and then the potential reduction in outputs if it arrives, spreads and becomes established as a pest.

Cost-benefit analysis scenarios

For the cost benefit analysis, the situation of its incursion without any response is the counterfactual "do nothing" scenario. The analysis then compares three separate response scenarios:

- Option 1: A **do minimum** option, in which growers respond with local measures as and when BMSB is found – reducing crop losses by 15% on average relative to the counterfactual
- Option 2: A **precautionary chemical** response, in which growers increase use of chemical pesticides to manage BMSB, incurring additional costs and

[1] See pages 27-28 of https://www.mpi.govt.nz/protection-and-response/finding-and-reporting-pests-and-diseases/keeping-watch/surveillance-magazine/ for examples of BMSB at the New Zealand border.

risks of dealing with chemical residues – crop losses are on average 50% less than the counterfactual

- Option 3: A response with **introduction of biological control agent** (the Samurai Wasp), to reduce the costs and risks of enhanced chemical use – crop losses are on average 75% less than the counterfactual scenario.

For each option the quantified costs are the incremental costs relative to the counterfactual, for horticultural growers directly affected by the incursion. The quantified benefits are the reductions in production losses, relative to the counterfactual, for those growers.

The cost benefit analysis covers a 20-year period an uses Treasury's current recommendation 6% discount rate for 'general' projects or interventions. Indirect effects that flow on to other sectors (such as other parts of the primary sector, or manufacturing firms) are excluded from this CBA but covered in the CGE analysis.

We also explore other potential BMSB-related costs and benefits, such as the impact on households and gardeners, in a qualitative way given an absence of reliable information or data.

Main findings

As BMSB has yet to appear in New Zealand, this analysis infers impacts from the experience of BMSB incursions overseas. The available evidence points to substantial economic, social and environmental costs should BMSB become established in New Zealand, causing losses across a range of productive sectors and crops.

There are benefits of introducing a BCA but there are trade-offs to be made. Introducing a BCA has multiple benefits:

- reduced use of chemical spray.
- improved produce quality, both for crops targeted by BMSB and other non-target species currently protected by integrated pest management systems which could be disrupted by chemical responses to BMSB.
- support for government export and regional development objectives.
- societal gains, including for households, amenity and gardeners.

The profile of costs of the three response options is summarised in Figure 1. This shows the S-shaped diffusion curve which peaks in 2026 and then flattens off – although in the graph it appears to decline past that date, because of discount rate at that point is greater than the rate of further expansion of BMSB.

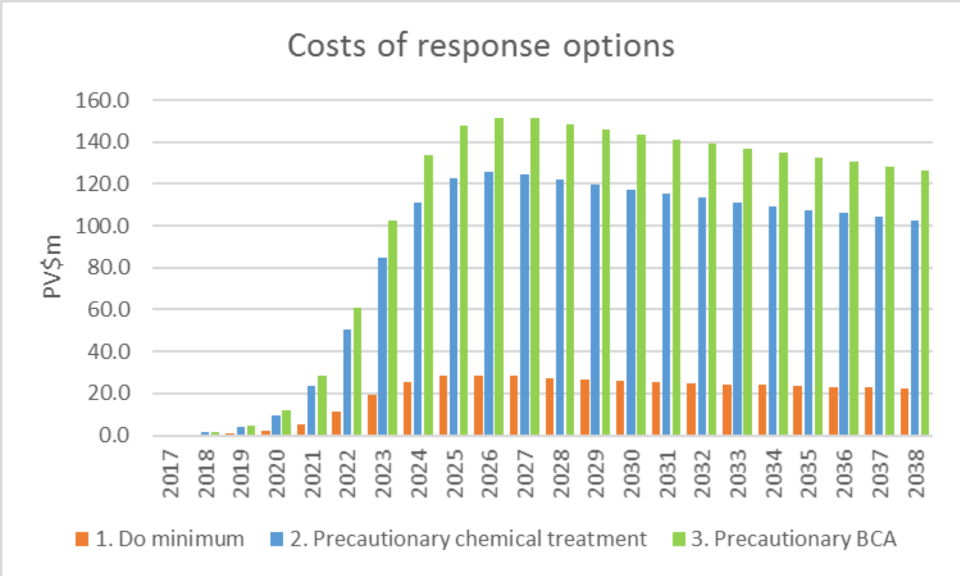
The graph also shows that Option 2, the precautionary chemical treatment, is substantially more costly than the do minimum Option 1. Option 3 which involves precautionary use of the BCA is moderately more costly than Option 2.

We do not report the costs and benefits of the 'do nothing' option, as it acts as the counterfactual in this CBA. However, we have estimated the potential impacts of BMSB in this scenario as part of the economic modelling for our accompanying report.[2] The modelling shows that in the "do nothing scenario" by 2038 real GDP falls by $4.1 billion. Export volumes fall by $1.2 billion.

[2] NZIER. 2017. 'Quantifying the economic impacts of a Brown Marmorated Stink Bug incursion in New Zealand: A dynamic Computable General Equilibrium modelling assessment'. Report to Horticulture New Zealand, June 2017.

Figure 1 Cost of responses to BMSB

Present value 2018-2038, $ millions



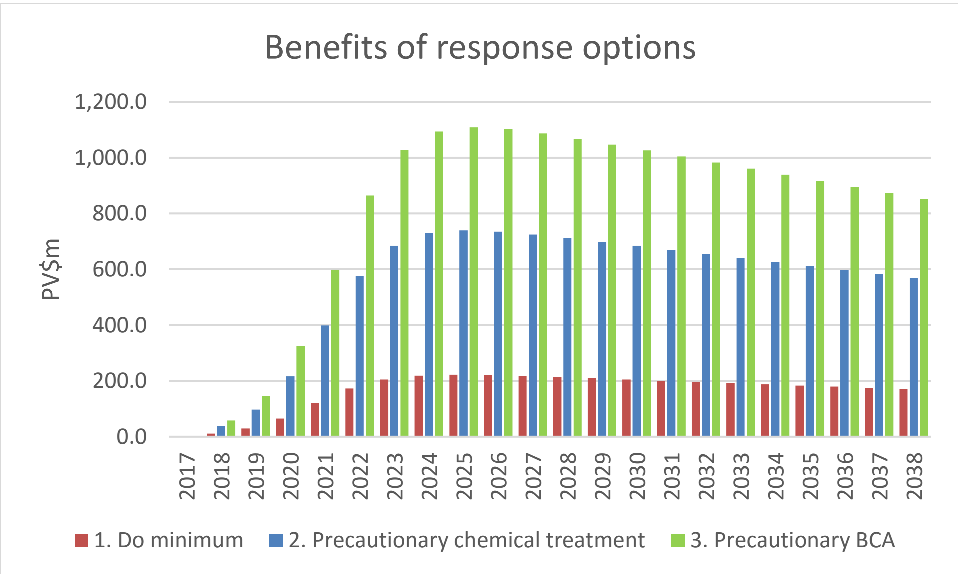
Source: NZIER

The profile of benefits of the three response options is summarised in Figure 2. It shows a similar relativity between the three options, and a similar curved profile as the potential impacts (and impacts avoided) are directly proportional to the area affected and the diffusion pattern across the country.

Note that the left-hand axis in this figure is almost an order of magnitude larger than that in Figure 1, as the costs of each response option are relatively small compared to the benefits expected from them.

Figure 2 Gross benefits of the response options

Present value 2018-2038, $ millions

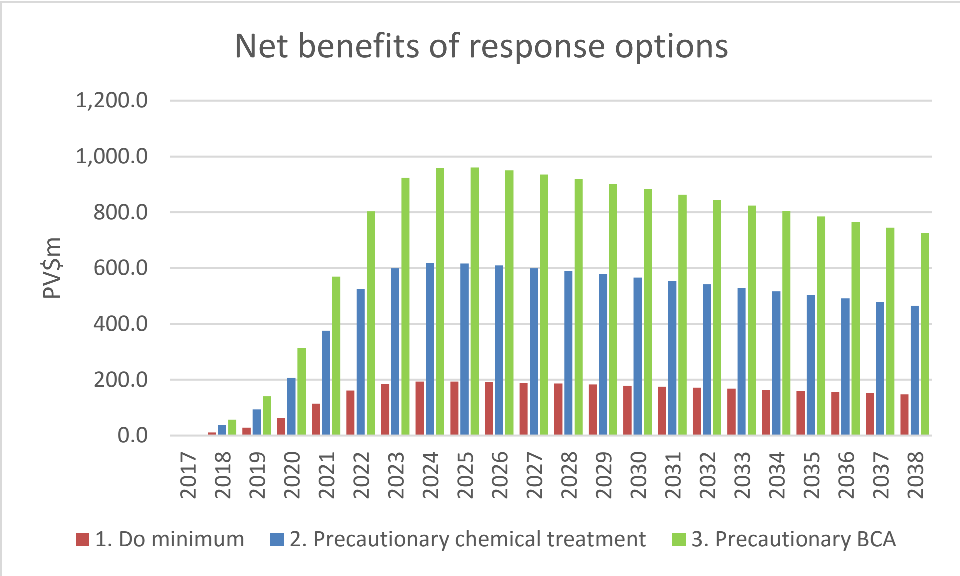


Source: NZIER

The net benefits of the three options are summarised in Figure 3.

Figure 3 Net benefits of response options

Present value 2018-2038, $ millions



Source: NZIER

The results underpinning these graphs are presented in Table 1. Of the three options, the BCA has the largest net benefit, with present value of $15.6 billion over the 20-year analysis period. The precautionary chemical intervention has a net benefit of PV $10.1 billion and the do minimum option a net benefit of PV$ 3.1 billion.

Table 1 Cost and benefit results of the different options

	0. Do nothing	1. Do minimum	2. Chemical response	3. BCA response
Benefits PV $m	0	3,594	11,981	17,972
Costs PV $m	29,651	423	1,887	2,301
Net benefits PV $m	**-29,651**	**3,172**	**10,095**	**15,671**
Benefit Cost Ratio		8.5	6.4	7.8

Source: NZIER

Table 1 also shows benefit cost ratios of the three options.

The highest benefit cost ratio is in the do minimum option, which means that for relatively low cost it achieves the highest benefit per dollar expended.

The second highest BCR is for the BCA response, which has a higher return per dollar expended than the chemical response.

Although the BCA costs more than the do minimum, it also delivers five times as many benefits (avoided crop losses). The present value of the BCA's net benefits are therefore almost five times as high as those in the do minimum option.

We note that there is some uncertainty over the BCA's effectiveness in New Zealand. However, the sensitivity analysis below indicates that if the BCA helped avoid even 10% of the expected crop losses in the do nothing scenario, it would still break even.

Scientific literature suggests there is a "classical BCA profile" in which introduction costs are incurred only at the initial introduction of the BCA, which then becomes attached to the pest population, moves with it and regulates it as it goes. If so our modelling costs of BCA introduction could be overstated. We model in Appendix C an alternative profile of BCA introduction which lowers the costs of BCA to about a third of those of the precautionary chemical option.

This results in the net present value and benefit cost ratio of the BCA option being the highest of the three options. However, in view of some uncertainty as to whether the Samurai wasp would establish itself in a population of BMSB moving across New Zealand, we suggest our original modelling be viewed as a conservative estimate on the assumption that it does not, with the Appendix C results indicating a more optimistic scenario in which it does conform to the classical BCA profile.

Interpretation

The results of this cost benefit analysis suggest that if the BMSB arrives and becomes established in New Zealand, the response that would minimise its adverse effects (i.e. deliver the greatest net benefit) would be with the use of the biological control agent. The horticulture sector as a whole and each of its product groups would gain benefits from so doing.

These results are dependent on assumptions and different inputs would yield different results. The critical assumptions are the relative costs and expected benefits between each sector.

Sensitivity analysis

The size of the NPV and BCR suggests large changes could be made to input assumptions and still result in positive net benefits. The BCA option would break even if its costs were 7.8 times larger than those assumed here, other things held constant.

Conversely, the response options could still break even with much lower benefits than those in the base assumptions. Other things held constant, it would require only

- 1.8% reduction in production losses (rather than 15% in the base assumptions) for the do minimum option to break even;
- 7.8% reduction (rather than 50%) in production losses for the chemical response to break even; and
- 9.6% reduction (rather than 75%) in production losses for the BCA response to break even.

If the costs of precautionary responses are assumed to arise as soon as the BMSB arrives (rather than being introduced in accord with the S-shaped diffusion curve assumed for BMSB), the net present value and benefit cost ratios of all response options shrink in size, but all remain positive and the BCA option remains the one that provides the largest net present value.

Unquantified costs and benefits

Reports of BMSB incursions overseas show adverse effects on domestic gardens and infestation of houses. We have not quantified these for want of evidence on the scale of such impacts in New Zealand conditions. However, these impacts mean there is a societal cost of BMSB over and above that estimated for productive sectors, and societal benefit in measures to suppress BMSB populations (like BCA).

Most of the assumptions in this analysis are derived from overseas studies, a limited number of New Zealand studies, and scientific opinion. These studies and opinions give us an incomplete window on actual performance since there is a degree of uncertainty about the impact of the proposed BCA in the New Zealand habitat.

The degree of uncertainty extends to the likely impacts on crops and the impact on rare native species. Given this uncertainty caution is needed in interpreting the quantified benefit calculations.

Before introducing a biological control agent, the Environmental Protection Agency needs to be satisfied that all impacts have been assessed and considered. This includes impacts on native species and human health. Information on the Samurai Wasp's potential impacts in a New Zealand setting is limited and currently uncertain.

However, the wasp has characteristics that make it likely to be an effective BCA, including co-evolution with BMSB to specifically parasitise it. Previous experience with a related organism introduced in New Zealand in the 1940s to target the Green Vegetable Bug has been both effective in suppressing the GVB and shown no sign of widening its diet to indigenous organisms.

Biological assessment is beyond the scope of this report, but should the Samurai wasp be approved for use in New Zealand **there is high likelihood that it will provide net benefits in response to incursion by BMSB**.

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1. Introduction

This report provides an indicative estimate of the costs and benefits of options to combat the Brown Marmorated Stink Bug (BMSB, *Halyomorpha halys*), including introducing the Samurai Wasp (*Trissolcus japonicas*) into New Zealand as a bio-control agent (BCA).

BMSB is an agricultural pest originating in East Asia, which feeds on fruit trees, field crops and woody ornamentals. Since 1996 established populations have been found in USA, Switzerland, France, Germany and Italy. It has caused both economic damage in the loss of commercial crop production and costs of measures to counter it, and a public nuisance because of its damage to residential gardens, infestation of housing and its unpleasant smell.

It has not yet been found in New Zealand, but could potentially arrive through a wide range of pathways, including imported goods and transport equipment and travellers' personal effects. The Ministry for Primary Industries reports increasing numbers of BMSB being detected at the border.[3]

It has been reported detected in Chile thus surviving in a Southern Hemisphere setting after travelling from its Northern Hemisphere natural habitat.

This report describes a cost benefit analysis of 3 options in response to an incursion of BMSB. Should an incursion occur – and recent reports of the number of infestations of goods detected at New Zealand's borders suggest it is only a matter of time before sufficient BMSB slip into the country to establish breeding populations – New Zealand has four broad options:

- Do nothing and ignore it, the result of which would be the establishment and spread of BMSB around the country, incurring costs of unmitigated crop losses from the BMSB's eating of crops close to picking stage
- Do the minimum necessary to contain the damage as and when BMSB are detected in an area, which will reduce crop losses somewhat from the unmitigated damage in the do-nothing option
- Take precautionary action with increased chemical treatment of fruit crops to deter feeding by BMSB and reduce crop losses, but this also increases risk of loss of crop value due to export market responses to the perception of lower produce quality and enhanced chemical residues
- Take precautionary action with introduction of a BCA such as the Samurai wasp, which parasitises the eggs of BMSB and reduces its presence in affected areas and the consequent damage it causes.

These scenarios are examined in a companion NZIER report on *Economic Impacts of a BMSB Incursion in New Zealand*, which uses a computable general equilibrium (CGE) model of the economy to estimate the economy-wide impacts of such an incursion, taking account of reallocation of resources across industry sectors in response to the impacts.

[3] See pages 27-28 of https://www.mpi.govt.nz/protection-and-response/finding-and-reporting-pests-and-diseases/keeping-watch/surveillance-magazine/ for examples of BMSB at the New Zealand border.

This report uses data from the same model in a cost benefit analysis (CBA) of the different response options. CBA is a partial equilibrium analysis which concentrates on the impacts of the incursion and response options in sectors and activities directly affected by the incursion, and compares each option's benefits relative to doing nothing with the costs of so doing.

A CBA can consider some impacts (such as effects on quality of life in houses infested by BMSB) which are not covered in the CGE model, and it can provide an indication of the Social Return on Investment in tackling the pest incursion.

1.1. Background literature on BMSB

BMSB has emerged relatively recently as a potentially cosmopolitan pest outside its home range in China, Korea, Japan and Taiwan, with the growth in trade with the East Asian region. It has been recorded in the USA since the mid 1990s and from around 2010 it has been a significant pest in the areas it has become established in the USA, Switzerland, France and Italy. In the USA it has had major impact on apples and other fruits grown in New Zealand, and in Italy it has been found to damage kiwifruit crops.

BMSB is an arboreal species which lives and breeds in woody vegetation but moves into adjoining commercial crops to feed on maturing fruit. This "interstitial" habitat means that it may be possible to confine BMSB impacts to the edges of crops by attracting them to sacrificial plants on the margins; but short term management options are for increased chemical applications to deter BMSB from feeding on crops, or reducing their number with pesticides or biological control agents. BMSB feeding leaves commercial fruits blotchy, dimpled, discoloured and rendered unmarketable.

BMSB tends to overwinter in buildings, and infested houses can be tainted by smell and are difficult to clear.

In New Zealand the Ministry for Primary Industries prepared a Risk Assessment of BMSB (*Halyomorpha halys*) in 2012 which found that although BMSB was not yet present in New Zealand it was capable of hitch-hiking into the country on cross-border merchandise and in travellers' luggage. It assessed the economic consequences of establishment as likely to be moderate to high; the environmental consequences to be low; the socio-cultural consequences likely to be moderate; but there were unlikely to be adverse effects on human health.

In 2014 Rice et al expanded on the biology, ecology and potential management of BMSB, characterising it as a generalised herbivore with over 100 host species from 49 plant families, with a tendency to attack fruit just as it is becoming ready to harvest. The pesticide applications used internationally in response to BMSB can disrupt integrated pest management systems, killing off beneficial insects and risking secondary outbreaks of other pests.

Charles (2015) argued that biological pest control would be necessary to tackle BMSB to avoid the consequences of higher chemical applications, and that the Samurai Wasp (*Trissolcus japonicus*) is the most likely candidate, being a native of the region where BMSB originates and having co-evolved specifically to parasitise it.

There is a risk that discovery of viable populations of BMSB will not be made until after it has spread more widely than is feasible to attempt eradication, leaving control by natural enemies as an important tool in the armoury. Charles also notes that there is a precedent for such biological control, as a related species to *T. japonicus* was introduced into New Zealand in the 1940s to tackle another invasive pest, the Green Vegetable Bug (GVB), and had marked effects in reducing the damage associated with GVB without having much impact on non-target species (like some native organisms).

2. Method

CBA is a systematic process for calculating and comparing benefits, costs and risks of a decision regarding implementation of a policy or project, which can be used to determine either the net worth of proceeding and also for comparing different options for proceeding, to obtain the greatest net benefit from costs incurred.

It is an adaptation of investment appraisal methods from a societal perspective, accounting for effects that fall on more parties than a single firm or agency.

2.1. The CBA framework

A CBA proceeds by comparing a set of outcomes from a policy or project against a counterfactual that would prevail without that policy or project occurring. In the case of responses to potential incursion by the BMSB, the counterfactual that the policy choice is intended to counter is the establishment of BMSB and the associated costs that would entail.

Once a counterfactual is determined a baseline can be established in successive years in the future, against which to compare the options for responding to the BMSB incursion. Left to itself, the establishment of BMSB on New Zealand could have the following effects:

- Reductions in the value of commercial horticultural production among the crop species affected by BMSB
- Increases in the costs of pest management caused by the BMSB incursions (e.g. added inspections for sign of infestation, added treatments)
- Increases in the public nuisance of BMSB in damaging private property, including:
  - Damage to private gardens, which at the minimum could be valued at the cost of replacing damaged plants with more resistant species, but is probably more, reflecting the value of people’s preference not to be faced with the nuisance in the first place
  - Damage caused by infestation of buildings and homes, which at the minimum could be valued at the cost of clearing and cleaning buildings of infestation and associated smell, but is probably more reflecting people’s preference values.

The first two effects are on the value or costs for commercial operations, and therefore affect the economic surplus enjoyed by producers.

The third bullet refers to effects on people’s enjoyment of their properties, and therefore reflects the economic surplus obtained by consumers. The sum of changes in these producer and consumer surpluses is the measure of economic well-being calculated in a CBA.

In this analysis, the potential establishment of BMSB is examined over a 20 year timeframe from 2018 to 2037, assuming a hypothetical incursion in 2018.

The costs and benefits over this period are projected in real (constant dollar) terms and converted to present values by applying a 6% real discount rate, which is the

Treasury's current recommended rate for general applications. A project is generally considered worthwhile if the net present value of its cashflows is positive and its ratio of benefits to costs is greater than 1.

2.2. Counterfactual and options examined

The CBA projects the outputs of the potentially affected industries in the absence of the BMSB, and then the potential reduction in outputs if it arrives, spreads and becomes established as a pest. It then considers the effects of 3 alternative response options in terms of their implementation costs and their reduction in incursion costs (benefits).

For the cost benefit analysis, the situation of its incursion without any response is the counterfactual "do nothing" scenario. The analysis then compares three separate response scenarios:

- Option 1: A **do minimum** option, in which growers respond with local measures as and when BMSB is found – reducing crop losses by 15% on average relative to the counterfactual but incurring relatively low costs (added inspection for BMSB and spot pesticide treatments when found)
- Option 2: A **precautionary chemical respo**nse, in which growers increase use of chemical pesticides in anticipation of BMSB's arrival, incurring additional costs and risks of dealing with chemical residues – but reducing crop losses to on average 50% less than the counterfactual
- Option 3: A response with introduction of **biological control agent** (the Samurai Wasp), to reduce the costs and risks associated with enhanced chemical use – crop losses would be on average 75% less than the counterfactual scenario, pesticide costs are lower than Option 2 but there would be additional costs of applying and monitoring the biological control agent.

For each option the costs are the incremental costs relative to the counterfactual, for horticultural growers directly affected by the incursion. The benefits are the reductions in production losses, relative to the counterfactual, for those growers.

These options are in principle paralleled by options for private building owners (including residents). Home owners could do the minimum, hoping the BMSB does not infest their house then deal with it if it does; douse their houses with chemicals to deter entry of the BMSB; or apply a biological control agent.

They may have other options like physically sealing their buildings against pest incursion. But because home owners are likely to have less familiarity with handling pesticides or BCAs, many, if not most, may choose the do minimum option, or perhaps free-ride off the efforts of growers in the neighbourhood to keep BMSB numbers in check.

The costs and benefits for house owners are difficult to determine as they involve values that are not readily apparent in market transactions. These are not quantified in this analysis, but discussed more qualitatively when interpreting the results.

Indirect effects that flow on to other sectors (such as other parts of the primary sector, or manufacturing firms) are excluded from this CBA, in line with standard CBA procedures as provided in the Treasury's Guide to Cost Benefit Analysis. But such impacts are covered in the CGE analysis in NZIER's report on economic impacts of BMSB.

2.3. Assumptions on inputs

The do nothing scenario and different response options are built up with categories of benefits and costs as summarised in Table 2. The yield losses are estimated from specific assumptions for each crop, drawing on literature and discussions with industry experts on yield impacts anticipated should BMSB become established in New Zealand.

These are then applied to the forecast production of different crops, applying an S--shaped diffusion curve over 10 years implying slow spread of BMSB in early years, rapid expansion between years 2 and 7 then tailing off to cover 100% of crop areas from years 10 onwards.

It is unlikely that growers would sit back do nothing in the face of such options, so the three response options portray one reactive "do minimum" option and two "pre-emptive" options, one stepping up chemical treatment and the other using BCA.

Table 2 Categories of benefits and costs across options

Do nothing	Do minimum	Precautionary chemical	Precautionary BCA use
Yield losses (varying by crop)	15% reduction of yield losses	50% reduction of yield losses	75% reduction of yield losses
	Additional pesticide costs	Additional pesticide costs	Additional pesticide costs
	Additional labour costs for monitoring and spraying	Additional labour costs for monitoring and spraying	Additional labour costs for monitoring and application
	Higher capital cost for machine-sorting of crops	Higher capital cost for machine-sorting of crops	
		"Sacrificial" crop losses	
			Additional netting and BCA costs

Source: NZIER

Response options have some common categories, but assumptions across options differ. For instance, precautionary chemical application has much higher cost for additional pesticides than either the do minimum or the precautionary BCA (BCA has the lowest, but non-zero, additional chemicals of the three options).

The BCA option also has lower labour costs than the precautionary chemical option, but higher labour costs than the do minimum option. The largest component of the BCA option is the cost of additional netting and handling of the BCA.

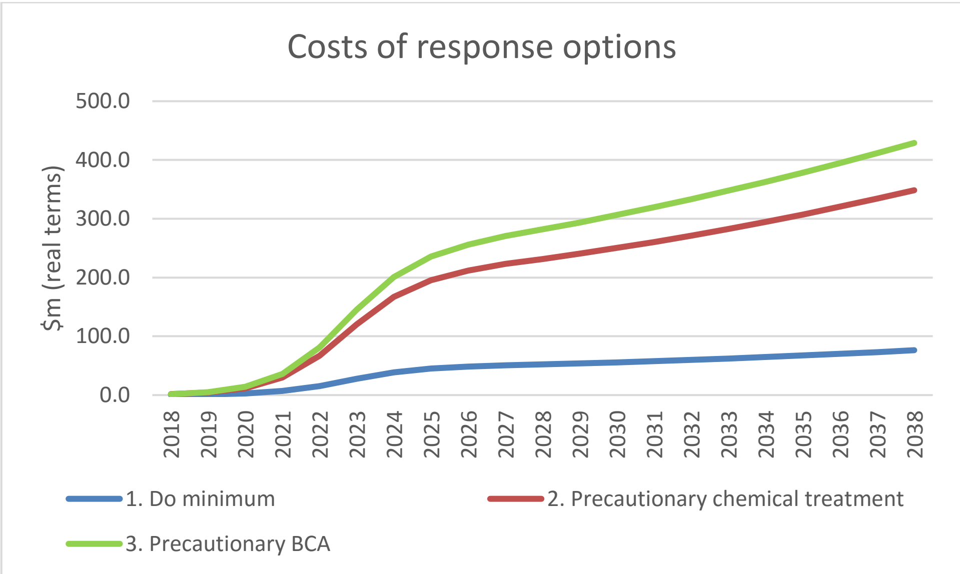
Compared to the do minimum option, the precautionary chemical option has higher pesticide costs that grow to about 4 times the do minimum costs in later years, and higher labour costs which climb to about 3 times as large. The precautionary chemical option also has capital costs for machine sorting of fruit that are about 50% greater than those for the do minimum option.

We also assume a cost category for precautionary chemical that none of the other options share, namely the "sacrificial" crop losses to divert BSMB away from the main crop, assumed to be a percentage of farm revenue lost for the different crops. While the precautionary BCA option could also include some sacrificial crops, we assume that the efficacy of the BCA in parasitising BMSB egg clusters and keeping population low would be sufficient to keep BMSB feeding contained to the margins of production areas, without planting alternative plants to attract them there.

The overall costs of the different response options are summarised in Figure 4 below. This shows the precautionary BCA option has the highest overall cost, followed by the precautionary chemical option. Both have substantially higher costs than the do minimum option, but also substantially higher benefits in reducing production losses under the counterfactual.

Figure 4 Costs over time of response options

Constant dollar terms



Source: NZIER

All cost profiles reflect the sigmoid diffusion curve assumed for the spread of BMSB across the country's growing areas. In the case of the precautionary chemical and BCA options, this implies that the area treated expands ahead of the spread of BMSB.

In practice this may not be how BMSB spreads: as an organism able to "hitch-hike" in freight traffic or private vehicles, once established in New Zealand it is possible that a breeding cluster of bugs could be transported well ahead of the diffusion frontier.

An implication of this is that precautionary measures may have to be spread wider than the current area of BMSB establishment, incurring higher costs that may not be matched by increased benefits if applied to areas where BMSB fails to appear. The effect of this on the results is examined in sensitivity analysis below.

3. Results and interpretation

As BMSB has yet to appear in New Zealand, this analysis infers impacts from the experience of BMSB incursions overseas. The available evidence points to substantial economic, social and environmental impacts and costs should BMSB become established in New Zealand, causing costs across a range of productive sectors and crops.

3.1. Central results

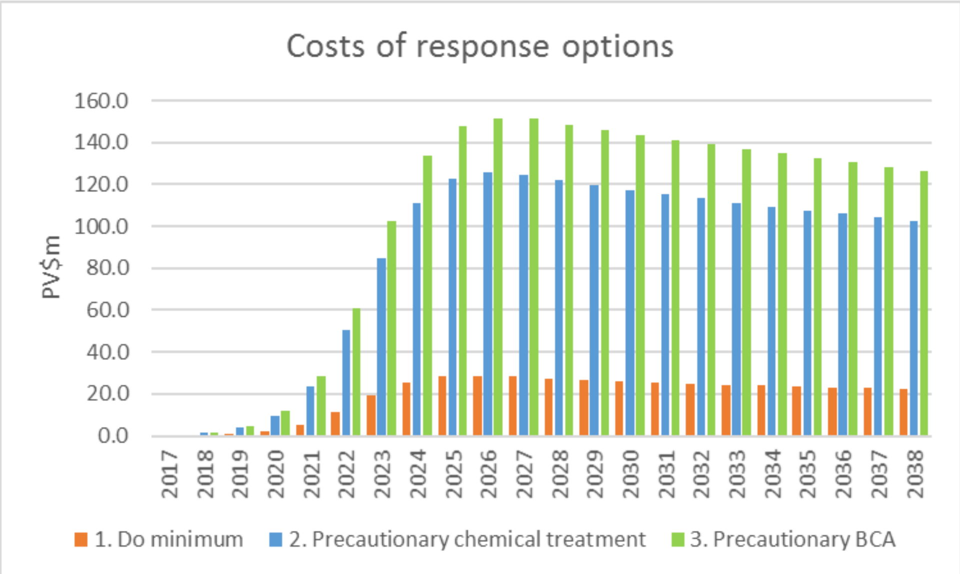
The profile of costs of the three response options is summarised in Figure 5 in present value terms. This shows the S-shaped diffusion curve which peaks in 2026 and then flattens off – although in the graph it appears to decline past that date, because of the effect of discounting (i.e. the discount rate at that point is greater than the rate of further expansion of BMSB).

The graph also shows that Option 2, the precautionary chemical treatment, is substantially more costly than the do minimum Option 1 in present value terms.

Option 3 which involves precautionary use of the BCA is moderately more costly than Option 2.

Figure 5 Cost of responses to BMSB

Present value 2018-2038, $ millions

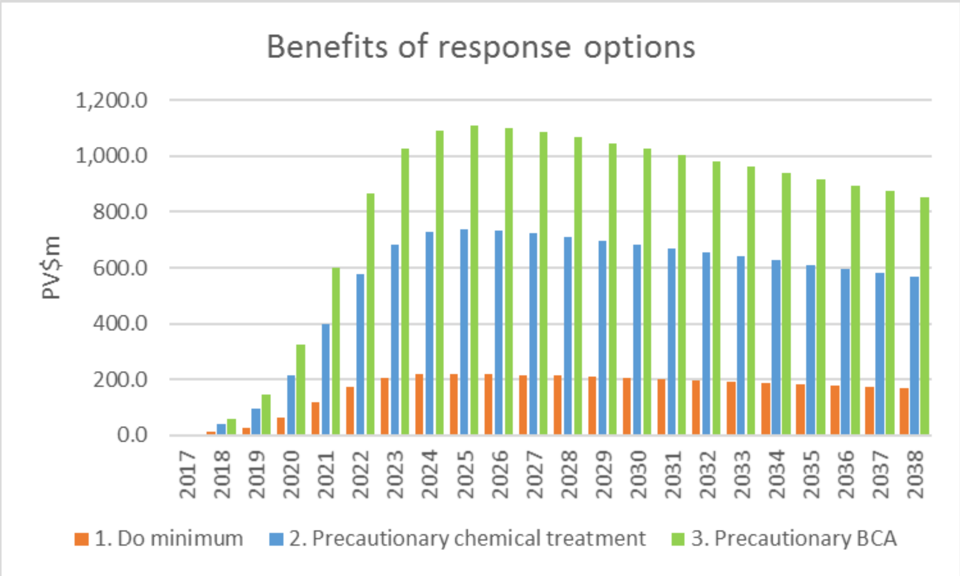


Source: NZIER

The profile of present value benefits of the three response options is summarised in Figure 6. This shows a similar relativity between the three options, and a similar curved profile. This is because the potential impacts (and impacts avoided) are directly proportional to the area affected and the diffusion pattern across the country. Note that the left-hand axis in this figure is almost an order of magnitude larger than that in Figure 5, as the costs of each response option are relatively small compared to the benefits expected from them.

Figure 6 Gross benefits of the response options

Present value 2018-2038, $ millions

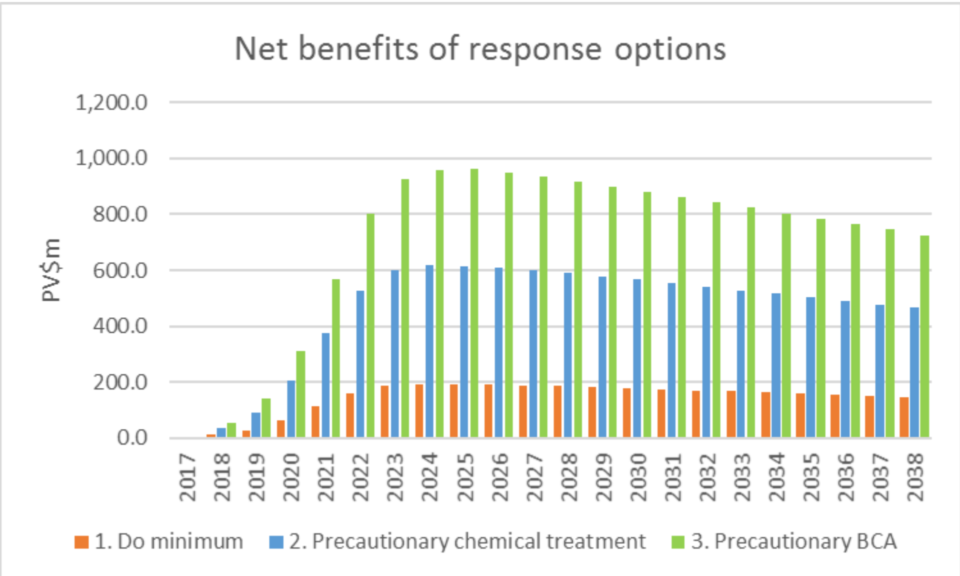


Source: NZIER

The net benefits of the three options are summarised in Figure 7.

Figure 7 Net benefits of response options

Present value 2018-2038, $ millions



Source: NZIER

The results underpinning these graphs are presented in Table 3. Of the three options, the BCA has the largest net benefit, with present value of $15.6 billion over the 20-year analysis period. The precautionary chemical intervention has a net benefit of PV $10.1 billion and the do minimum option a net benefit of PV$ 3.1 billion.

Table 3 Cost and benefit results of the different options

	0. Do nothing	1. Do minimum	2. Chemical response	3. BCA response
Benefits PV $m	0	3,594	11,981	17,972
Costs PV $m	29,651	423	1,887	2,301
Net benefits PV $m	**-29,651**	**3,172**	**10,095**	**15,671**
Benefit Cost Ratio		8.5	6.4	7.8

Source: NZIER

Table 3 also shows benefit cost ratios of the three options.

The highest benefit cost ratio is in the do minimum option, which means that for relatively low cost it achieves the highest benefit per dollar expended. However, taking such a ‘spot treatment’ approach would not address the risks of BMSB in any concerted way as it would not suppress the BMSB population significant.

The second highest BCR is for the BCA response, which has a higher return per dollar expended than the chemical response. Although the BCA costs more than the do minimum, it delivers a much higher net present value of benefits (avoided crop losses).

Offsetting this finding, however, there is more uncertainty about the efficacy of the BCA in achieving reduced crop losses in New Zealand, where it has not been used before. But if it is effective and reduces pesticides used in response to BMSB, it would reduce the risk of adverse consumer reactions to perceptions of chemical residues.

3.2. Sensitivity analysis

The size of the benefit cost ratios in these results indicates there is substantial latitude for changes in assumptions about costs and benefits without changing the expectation of benefits in excess of costs.

Put simply, other things held constant the costs could be 8.5 times larger than those assumed above and the do minimum options would still break even (i.e. achieve benefits equal to costs); or 7.8 times larger for the BCA option to break even, or 6.4 times larger for the precautionary chemical treatment to break-even.

Conversely, the response options could still break even if benefits were substantially smaller than those in the base assumptions. Other things held constant, it would require only

- 1.8% reduction in production losses (rather than 15% in the base assumptions) for the do minimum option to break even with benefits equal to costs;
- 7.8% reduction (rather than 50%) in production losses for the chemical response to break even; and
- 9.6% reduction (rather than 75%) in production losses for the BCA response to break even.

The break-even reduction in production losses is directly proportional to the costs of the different options, so the BCA option requires a higher efficacy than the chemical response.

Changing the estimated costs of the counterfactual results in different numbers in the analysis, but does not change the rank ordering of options by benefit cost ratio. Similarly, altering the discount rate between 4% and 10% does not change the rank, as the profiles of the three options are similar over time.

As mentioned above, it is possible that the precautionary options (chemical and BCA) may understate their costs in the early years of the analysis to the extent that they are based on the diffusion of BMSB. A precautionary approach may have to spread its attention more widely, as it does not know if or where BMSB might leapfrog the frontier to attack more crops. In the extreme a precautionary approach might apply across the full susceptible area from the start of incursion, increasing costs but not achieving proportional benefit at that stage.

Alternatively, a hybrid response might be used, with precautionary measures around the affected areas but a do minimum response for any sporadic outbreaks that occur beyond them. However, unlike the chemical response which requires repeated doses of insecticides to control the numbers of BMSB spreading to new areas, with the BCA the parasite will become established in the host population of BMSB and move with it as it spreads, requiring only small additional introductions in new areas. This would lower the recurring cost of the BCA over the long term.

To illustrate the potential of larger response costs, Table 4 illustrates the results of "saturation" precautionary action, in which the nationwide coverage of precautionary chemical and BCA applications achieved in 2027 in the base estimates is assumed to commence in 2018, on BMSB's arrival in New Zealand.

These estimates also conservatively assume the benefits are half the size of those in the base estimates.

Both the precautionary options still achieve net benefits, but their benefit cost ratios are much lower, at 2.9 for the BCA response and 2.4 for the chemical response. The do minimum option does not face any change in costs, but its benefits and benefit cost ratio are halved.

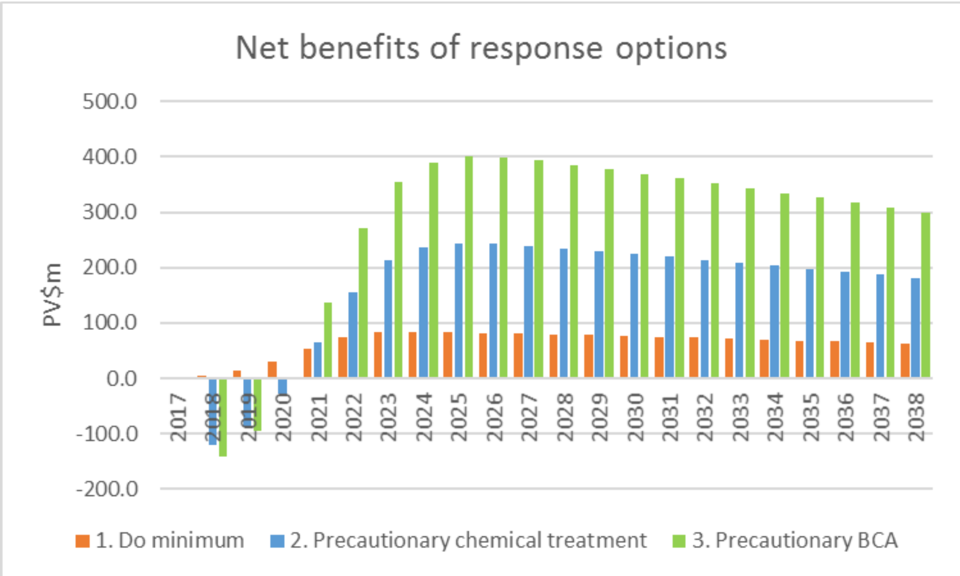
Table 4 Cost benefit results with "saturation" precautionary action

	0. Do nothing	1. Do minimum	2. Chemical response	3. BCA response
Benefits PV $m	0	1,797	5,991	8,986
Costs PV $m	-29,651	423	2,534	3,107
Net benefits PV $m	**29,651**	**1,374**	**3,456**	**5,879**
Benefit Cost Ratio	0	4.3	2.4	2.9

Source: NZIER

Figure 8 shows the net benefits of the options, with net cost in the initial years of the two precautionary options.

Figure 8 Net benefits of options with "saturation" action



Source: NZIER

3.3. Non-quantified factors

The above estimates suggest that, left untreated, the arrival and establishment of BMSB in New Zealand would have substantial costs for the horticultural industries, and that all three response options could be net beneficial in reducing those costs. The estimated net present values principally comprise the economic surplus for producers (relative to the counterfactual), but what of economic surpluses for consumers?

While BMSB may reduce the production of horticultural produce in New Zealand, it is not likely to change the international market prices for exported produce,[4] which effectively sets a cap on the prices for the same fruit in the domestic market.

[4] This applies to most fruits, but Kiwifruit is an exception, as New Zealand's production and trade can influence global prices.

Consequently, there should not be much impact on domestic prices, and to the extent that prices *do* change, that is just a redistribution of value between New Zealand consumers and New Zealand producers, which has no net impact on NZ Inc welfare. For some fruit in short supply there may be imports of the same fruit at higher prices or diversion of fruit from export streams. An increase in imports or reduction in exports would lower the income accruing to New Zealand, or there may be a demand response to lower domestic consumption.

The main consumer impact of relevance to CBA comes from the effects of BMSB on residents' environmental consumption, particularly BMSB's potential effects on ornamental garden plants, and on housing.

Householders and residential gardeners can respond to BMSB with their own private responses. However, residential property owners with small landholdings, limited familiarity with BMSB and differing priorities are unlikely to provide a comprehensive response to BMSB: their collective response may be subject to unawareness and free-riding behaviour.

Many are likely to opt for a do minimum or do nothing response with little effect on the prevalence of BMSB damage in their vicinity. Larger scale responses, however, could have positive spill-overs on their neighbourhoods.

Reports of house infestation by BMSB appear to be more numerous from the USA than from Europe, and there may be specific local factors that affect the extent of these impacts (Charles 2015). New Zealand, with a lower population and milder climate than American and European locations affected by BMSB, may be less prone to house infestation by overwintering BMSB.

Impacts on gardens are more likely. But none of these "residential" impacts can be quantified without geographical forecasting of the spread of BMSB, accounting for the density of housing adjacent to woody habitat and horticultural areas.

There is no evidential basis for such forecasting and it is beyond the scope of this current analysis.

What can be said is that measures to control the populations of BMSB are likely to provide some benefit for residents' consumer surplus, and that this will vary across the different response options. The do minimum option provides the least such benefit, as it is sporadic, reactive and depends on detection, which would allow BMSB to roam neighbourhoods until identified.

Both the precautionary options provide some spill-over benefit for neighbourhoods to the extent that they suppress the population of BMSB. However, the BCA option could be the better option for urban environments, where widespread chemical treatments may not be feasible or desirable.

There is some risk that the chemical response targeted at protecting commercial fruit may simply redirect BMSB to other food sources in unprotected residential gardens. The BCA, which focuses on reducing the reproduction of BMSB, may therefore be more effective where other options are not feasible in lowering local BMSB populations and the ensuing damage they cause.

This should provide households in urban areas with greater peace of mind, as the BCA would move with the BMSB population, reducing the need for spot treatment.

Without forecasting the number of gardens and houses affected there is no way to estimate the aggregate value of such impacts of BMSB for inclusion in the CBA. But in principle their value would reflect: the loss of home-produced fruit (valued at the market price of near equivalents); the cost of replacing plants with more resistant specimens, the cost of chemical treatments to salvage affected crops.

Avoiding these costs will likely make a small but positive addition to the net benefits of response options. As such our quantified net benefit figures are likely to underestimate the full net benefits to New Zealand.

3.4. The status of the BCA in New Zealand

The foregoing suggests that all response options are likely to provide net benefits given the arrival of BMSB, and that the largest net present value would be obtained by a biological control agent – the Samurai wasp. This BCA is not yet approved for use in New Zealand, but the CBA provides positive support for its approval.

In considering whether to approve use of a new organism, the Environmental Protection Agency requires information on the risks, costs and benefits of the new organism. These are the positive and adverse effects referred to in the HSNO Act.

The EPA considers the likelihood of occurrence (probability) and the potential magnitude of the consequences, and looks at distributional effects (who bears the costs, benefits and risks). Assessment requires considering all effects of a new organism's introduction to the New Zealand environment, including

- the potential for significant displacement of native species, deterioration of natural habitats or adverse effect to New Zealand's genetic diversity
- its likelihood of causing disease, acting as a parasite, or becoming a vector for animal or plant disease
- impacts on human health and safety
- the principles of the Treaty of Waitangi and the relationship of Māori to the environment, and
- potential impacts on society, the community, the market economy and New Zealand's international obligations.[5]

There are benefits of introducing a BCA but there are trade-offs to be made.

Introducing a BCA can have multiple benefits:

- reduced use of chemical sprays
- improved quality of produce, both for crops targeted by BMSB and other non-target species which currently gain protection from integrated pest management systems which could be disrupted by chemical responses to BMSB
- societal gains for traditional and amenity gardeners, and house owners
- support for government export and regional development objectives.

Weighing against are the costs and risks of a BCA:

- the cost of procuring the BCA

5 EPA Application form to release new organisms with controls

- the risk of unintended consequences of BCA, particularly the potential for impacts on New Zealand's indigenous species
- societal aversion to introducing more exotic species into New Zealand.

The government has ambitious economic growth targets driven by expectations of increasing the value of exports. Strong growth is anticipated for horticulture, meat and seafood to offset halting growth in dairying, and government's Business Growth Agenda also aims at all regions having opportunity to grow and prosper. **BMSB is a threat to these government aims which introduction of BCA can alleviate.**

Populations of the Samurai wasp already exist in laboratories in the USA, where they are being tested for potential impacts and suitability for release into the environment. A New Zealand-based risk analysis (Charles 2015) has already suggested **the Samurai wasp has characteristics favourable to its safe use in New Zealand**, it being:

- an organism that has co-evolved with BMSB specifically to parasitise it
- related to another organism introduced into New Zealand in the 1940s, which has proved successful in suppressing the invasive Green Vegetable Bug (GVB) without expanding its diet to indigenous species.

This CBA suggests that despite some uncertainty as to effects and costs, biological control with the Samurai wasp provides significant net benefits over the next best alternative option examined on a similar basis. The net present value of the BCA option exceeds the next best option by more than $5 billion in the base estimates (Table 3) and over $2 billion in the more costly "saturation" estimate (Table 4).

The potential nuisance impacts of BMSB on households and domestic gardens would expand the overall benefit of response options, and possibly increase the incremental benefit of BCA over the next best alternative, on the assumption that it is less disruptive of integrated pest management systems and poses less risk of secondary pest outbreaks than the precautionary chemical response.

A **BCA may pose some risk to indigenous species and biodiversity. Although prior experience with the GVB suggests that risk to non-target species is not significant, the impact of the Samurai wasp is unknown**. The alternatives of responding with precautionary chemicals or leaving BMSB unchecked are also not without risk to indigenous biodiversity, in addition to the increased economic cost they would entail. The risks of Samurai wasp could be reduced by examining its effect on potential other species in contained laboratory settings, and by planning for adaptive management once it is released.

Key points from this analysis in support of application for use of Samurai wasp in New Zealand are outlined below.

- BMSB if it becomes established in New Zealand poses a threat of significant losses to horticultural production, estimated in the CBA as $1.8 billion in the first year and rising, compared to the horticulture industry's current output of around $7.5 billion (including exports of $4.3 billion)
  - This is large enough to potentially impact on national economic growth aims and regional employment and incomes
- Three response options examined in this CBA are all likely to provide benefits (reduction in losses) greater than their costs of implementation

- The reactive do minimum option has lowest implementation cost and highest return per dollar input, but aggregate net benefit is small
  - The precautionary chemical option has higher implementation and higher aggregate net benefit, but poses some risk of value loss from consumer perceptions about enhanced residual chemicals and secondary losses from disruption of integrated pest management
  - The precautionary BCA approach has higher costs than the chemical option and the largest aggregate net benefits of all options. While it has been successful overseas, there is some uncertainty about its efficacy in New Zealand
- The CBA results of all three options have sufficiently large net benefits and benefit cost ratios to be robust to changed assumptions, showing positive net benefits even with cost higher, and benefits lower, than the base assumptions
- Suppression of BMSB populations would also reduce damage to domestic gardens and house infestation – these cannot be quantified or valued on current data but would be an additional societal benefit of control
- The Samurai wasp has characteristics suggesting it could be a successful BCA for introduction in New Zealand
  - It has evolved as a specific parasitoid of BMSB, and works to suppress population regeneration and growth
  - Introduction of a related species to New Zealand for Green Vegetable Bug has suppressed population and damage caused, but has had low environmental impact on indigenous species and biodiversity.

In summary, **the threat of BMSB is significant**, comprising a moderate-high impact (about $1.8 billion, or 22% of current horticultural output, lost in the first year) and moderate-high likelihood of occurrence through hitchhiking (MPI 2012).

The **socio-economic benefits of Samurai wasp are likely to be high-moderate** in view of potential reductions in losses, and impacts on the natural environment are low (Charles 2015). Impacts of the BCA on human health and cultural issues are beyond the scope of this report.

3.5. Comparison to CGE economic impact results

A companion NZIER report to this one on *Quantifying the Economic Impacts of a Brown Marmorated Stink Bug Incursion in New Zealand* describes some computable general equilibrium (CGE) analysis modelling of the same scenarios used in this CBA.

That report examines the economy-wide effects of an incursion, allowing for impacts on input prices and returns from different activities, and the reallocation of input resources across sectors. In short it covers the flow-on effects across sectors beyond just horticulture.

It found that the BCA option reduces the cost of BMSB by 50% compared to the counterfactual. It estimates losses for economy-wide real GDP rising to $1.8 billion to $3.6 billion per year by 2038, and a fall in export volumes of $312 million to $554 million per year by 2038. The CGE modelling also suggests that employment is likely to fall by 0.5% to 1.1% over the same period, and real wages fall by 0.45% to 1.0%.

The model's measure of economic well-being, a measure of consumer surplus, would fall by $2.8 billion under the do minimum options and $1.4 billion with the BCA option.

The CGE analysis and this CBA model the same options and use the same cost data, but are also fundamentally different in approach.

The CGE analysis models impacts across the whole economy allowing for resource reallocation across sectors. While there is some reallocation of resources into other sectors over time, the overall level of demand for labour in the New Zealand economy falls after BMSB arrives, due to production losses imposed on one of its key inputs (horticultural land). BMSB is big enough to have national repercussions.

The CBA is a partial equilibrium analysis and focuses on the effects on the sectors directly affected by BMSB. It explicitly looks at response options as investments to avert losses, and estimates costs and benefits over time to work out which provides the best return over time for the affected sectors.

The principal component of welfare measured in this CBA is a producer surplus for the owners of horticultural businesses. Consumer surplus effects are acknowledged for householders and residents but not quantified in this analysis.

3.6. Caveats on the estimates

Since there is no scientific evidence available on how BMSB would fare in New Zealand conditions, we rely on international experience and the professional judgement of industry experts and officials to shape our scenarios.

Estimating the precise economic impacts of BMSB on New Zealand is subject to numerous assumptions, all of which have a high degree of uncertainty attached to them. As more information and data becomes available on the likely spread of BMSB and the on-orchard costs associated with its treatment, we will be able to carry out further economic modelling as required.

Feedback on the first draft report noted that the modelling of the BCA did not conform to the "classical" BCA pattern, in which the BCA becomes embedded in the pest population and moves with it across the country. This means there need only be one introduction of the BCA, with subsequent top-up introductions only required when new invasion occurs from a pest source without the BCA, or to provide additional control where the BCA population appears to be thin. If this is so, our modelling of repeated introductions aligned to the spread of BMSB would overstate the costs of the BCA option.

Scientific literature does support the classical BCA profile incurring introduction costs only at the initial incursion, although from the literature we have seen in nearly half the reported cases the BCA fails to become established with the host pest species.

We model an alternative "classical BCA" introduction in Appendix C. The effect of this is to lower the costs of BCA to about a third of those of the precautionary chemical option, but still about double those of the do minimum option. The net present value and benefit cost ratio of the BCA option would then be the highest of the three options.

There remains however some uncertainty as to whether the Samurai wasp would establish itself in a population of BMSB moving across New Zealand. Therefore, we suggest our original modelling be viewed as a conservative estimate on the assumption that it does not, with the Appendix C results indicating a more optimistic scenario in which it does conform to the classical BCA profile.

4. Conclusions

This report provides an indicative estimate of the costs and benefits of various options for combatting the Brown Marmorated Stink Bug (BMSB) should it arrive in and become established in New Zealand. This includes introduction of the Samurai Wasp into New Zealand as a bio-control agent (BCA) to combat the spread of BMSB.

The results of this cost benefit analysis (CBA) suggest that **if the BMSB arrives and becomes established in New Zealand, there would be substantial costs for the horticultural industries** due to damage to crops. This CBA compares the effects of a reactive do minimum response in treating BMSB outbreaks when they occur, and two precautionary approaches using either chemicals or a BCA.

The analysis finds that **the response that would have the highest net present value of reduced damage would be with the use of the BCA**. The horticulture sector as a whole, and each of its product groups, would gain benefits from so doing.

The size of the NPV and BCR suggests large changes could be made to input assumptions and still result in positive net benefits. The BCA option would break if its costs were 7.8 times as large as those assumed here, other things held constant.

Results remain positive and the BCA option remains the one that provides the largest net present value even with a "saturation response" that treats areas far wider than those where the BMSB has been found.

The CBA provides quantified estimates for impacts on the horticulture sector. Any widely applied **measures that suppress the BMSB population would also have spill-over benefits for the household sector**, reducing damage to domestic gardens and reducing the risk of infestation of houses by the BMSB.

These results are dependent on assumptions and different inputs would yield different results. The critical assumptions are the relative costs and expected benefits between each sector.

Most of the assumptions are derived from overseas studies, a limited number of New Zealand studies, and scientific opinion. These studies and opinions give us an incomplete window on actual performance. The BCA has been an effective control overseas, including in like climates, but there is a degree of uncertainty about the impact of the proposed BCA in the New Zealand habitat.

The degree of uncertainty extends to the likely impacts on crops and the impact on rare native species. Given this uncertainty caution is needed in interpreting the quantified benefit calculations.

Before introducing a biological control agent, the Environmental Protection Agency needs to be satisfied that all impacts have been assessed and taken into account, including impacts on indigenous species and human health. Information on the Samurai Wasp's potential impacts in a New Zealand setting is limited and currently uncertain. However, initial risk assessments suggest the Samurai wasp has characteristics that make it likely to be an effective BCA.

Should the Samurai wasp be approved for use in New Zealand this CBA indicates there is high likelihood that it will provide net benefits as an effective response to incursion by BMSB.

Appendix A References

Basse B., C.B. Phillips, S. Hardwick and J.M. Kean *(2015)* Economic benefits of biological control of *Sitonaobsoletus* (clover root weevil) in Southland pasture *New Zealand Plant Protection 68: 218-226*

Charles JG (2015) "Preparing for classical biological control of Brown Marmorated Stinkbug in New Zealand: why CBC will be necessary, and the potential environmental impact of an exotic egg parasitoid, *Trissolcus japonicas";* NZ Institute for Plant and Food Research Ltd

Grundy TP (1989) An economic evaluation of biological control of rose-grain aphid in New Zealand, Research Report 200, Agribusiness and Economics Research Unit, Lincoln University

Ministry for Primary Industries (2012) "Risk analysis of *Halyomorpha halys* (brown marmorated stink bug) on all pathways" – Risk Analysis, New Zealand Government

Rice, Kevin B., Chris J. Bergh, Erik J. Bergmann, Dave J. Biddinger, Christine Dieckhoff, Galen Dively, Hannah Fraser, Tara Gariepy, George Hamilton, Tim Haye, Ames Herbert, Kim Hoelmer, Cerruti R. Hooks, Ashley Jones, Greg Krawczyk, Thomas Kuhar, Holly Martinson, William Mitchell, Anne L. Nielsen, Doug G. Pfeiffer, Michael J. Raupp, Cesar Rodriguez-Saona, Peter Shearer, Paula Shrewsbury, P. Dilip Venugopal, Joanne Whalen, Nik G. Wiman, Tracy C. Leskey, and John F. Tooker (2014) "Biology, Ecology, and Management of Brown Marmorated Stink Bug (Hemiptera: Pentatomidae)" *Journal of Integrated Pest Management* 5(3)

Treasury (2015) *Guide to Social Cost Benefit Analysis*, Wellington http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/guide

Zeddiesa J., R.P. Schaaba, P. Neuenschwanderb, H.R. Herren (2001) Economics of biological control of cassava mealybug in Africa, *Agricultural Economics* 24,209-219

Appendix B Impact assumptions

Table 5 Summary of modelling scenarios

	0. Do nothing	1. Do minimum	2. Precautionary chemical treatment	3. Precautionary BCA
Average yield loss	26%	22%	13%	8%
Additional pesticide costs	-	10%	30%	5%
Additional labour costs, hours p/w	-	1.5	4.5	3
Higher capital costs	-	5%	7.5%	-
Cost of sacrificial crops	-	-	2%	-
Additional netting costs, % of opex	-	-	-	5%

Source: NZIER – *Quantifying the economic impact of an BMSB incursion in New Zealand*

Appendix C Alternative Scenario

Industry feedback on an earlier draft of this report suggested the modelled results for its BCA assessment do not conform to expectations for a "classical" biocontrol agent. With classical BCA the organism becomes embedded in the population of the pest species it is being applied to, so the BCA spreads across the country at the same time as its host.

In such circumstances, most of the costs of introducing BCA occur at its first introduction to the country, and subsequent releases are only needed if new infestations occur from overseas sources where the BCA is not present in the pest population, and if some augmentation releases of BCA are made to increase the impact on the pest population.

Our modelling of the BCA option has recurring costs throughout the analysis period, following the assumed diffusion pattern for BSMB across the country. Most of these costs however are not around the release of the BCA, but cover costs of farms in applying the BCA when BMSB moves into a new area, covering costs of meshing to help protect crops against BMSB and light applications of chemical pesticides. Some of these may not be recurring at such a high level if BMSB is known to be a host to the BCA, so it is useful to consider an alternative profile with lower recurring costs.

Support for the classic biocontrol profile is found in literature such as Bale et al (2008) who state "as soon as a natural enemy has been released and becomes effective, it contributes annually to benefits, while costs are minimal".[6] Chock et al (2010) find "biocontrol is often regarded as less costly than traditional methods despite the large initial investment".[7] But although many BCA evaluation studies have been published, few included any economic data.[8]

Some that do report substantial net benefits from a BCA that becomes attached to its host population and keeps its numbers and damage at a low level.[9] Page and Lacey (2006) review BCA programmes for 36 Australian weed pests, finding 15 of them return negative NPV.[10] MacFadyen's 2008 review of 33 Australian weed biological control programmes found that 9 produced no measurable benefits and seven produced benefits that were well below the costs of introduction.[11]

These are exceptions and most reports on effectiveness of BCA do not provide details of the profile of costs over time.

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6 Bale J. S., J. C. van Lenteren and F. Bigler (2008) Biological control and sustainable food production, *Phil. Trans. R. Soc. B* 363, 761–776

7 Chock, Megan, Kimberly Burnett, and Donna Lee (2010), An Economic Assessment of Biological Control for *Miconia calvescens* in Hawaii, Economic Research Organisation, University of Hawaii

8 McFadyen R. (2008) Return on investment: determining the economic impact of biological control programmes, XII International Symposium on Biological Control of Weeds

9 Greathead DJ (2004) Benefits and risks of classical biological control

10 Page A.R and K.L Lacey, AEC*group (2006)* Economic impact assessment of Australian weed biological control; Report to the CRC for Australian Weed Management

11 MacFadyen (op. cit.)

While *T. japonicas* is a specific parasitoid of BMSB in its home environment, there remains uncertainty about its likely effectiveness in New Zealand. MacFadyen's review implies that on average there is only around 50% likelihood of a given BCA being cost effective in tackling a pest.

Table 6 shows the results of an alternative comparison of options in which the BCA option has a more "classical control" profile over time, with most of the costs of introducing the BCA incurred in the first four years when BMSB spreads to cover 50% of its potential habitat, then declining to level out at a replacement rate from full habitat occupation after 10 years.

Minor adjustments are also made to the do nothing and chemical option to match this BMSB spread profile. Under this set of assumptions, the BCA option costs a little over twice the do minimum option and under a third of the chemical option, but would yield the highest gross benefit and net benefit of any option.

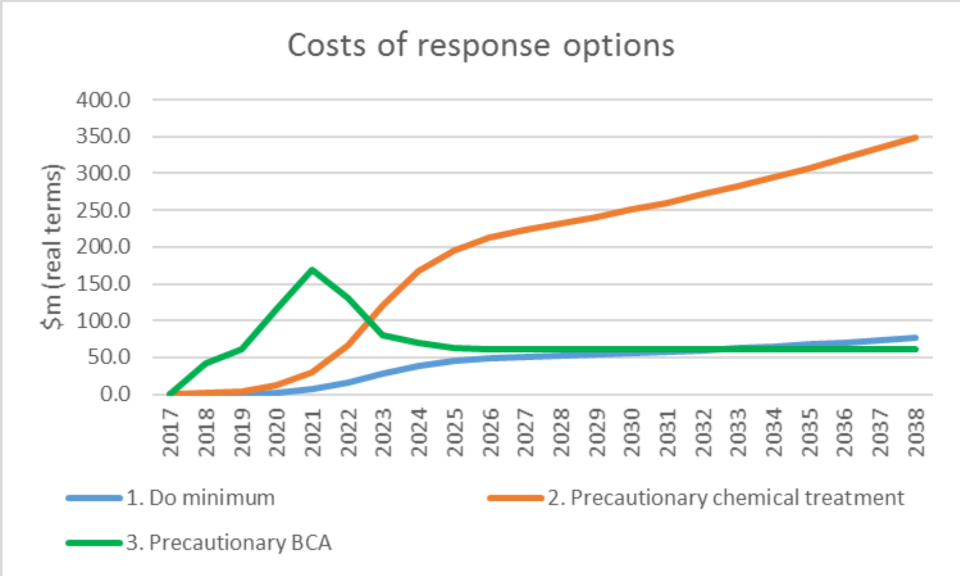
Table 6 Summary of scenarios with classic biological control

	0. Do nothing	1. Do minimum	2. Precautionary chemical treatment	3. Precautionary BCA
Benefit PV$m	0	4,437	14,789	22,183
Cost PV$m	-29,651	423	2,995	901
Net benefit PV$m	-29,651	**4,014**	**11,794**	**21,282**
Benefit cost ratio		10.5	4.9	24.6

Source: NZIER

Figure 9 shows the cost profiles of the three options under this classic biocontrol profile.

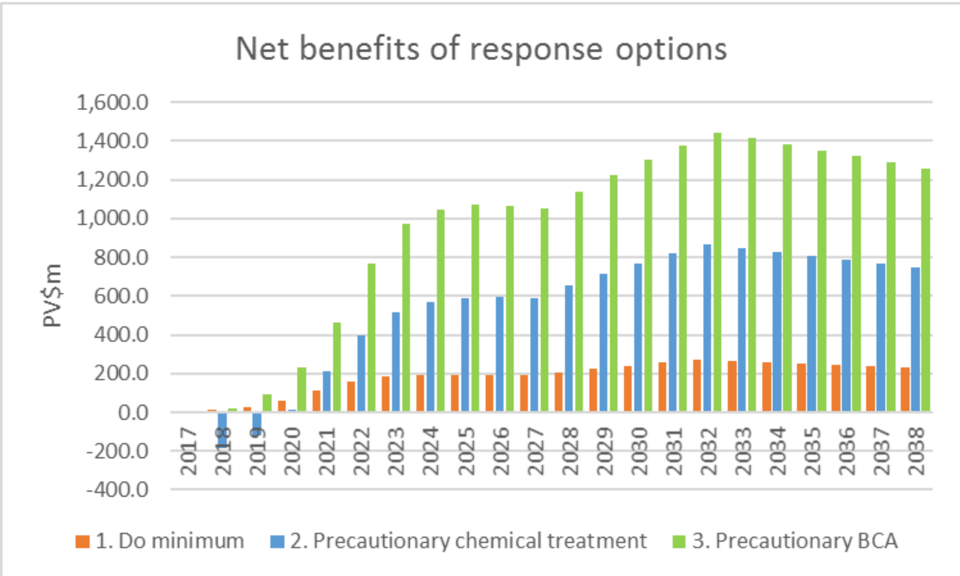
Figure 9 Costs of options with “classic” biocontrol profile



Source: NZIER

Figure 10 shows the present value of net benefits under the three options.

Figure 10 Net benefits of options



Source: NZIER

Because of uncertainties and assumptions used to work around them these results should be regarded as indicative only. If the BCA can be established in the BSMB population the likelihood of it providing the highest net benefits is substantially increased.