Impact assessment of the investment:

Development and implementation of protocols to enable importation of improved honey bee genetics to Australia (MT18019)

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Hort Innovation

Previous page image courtesy of MT18019

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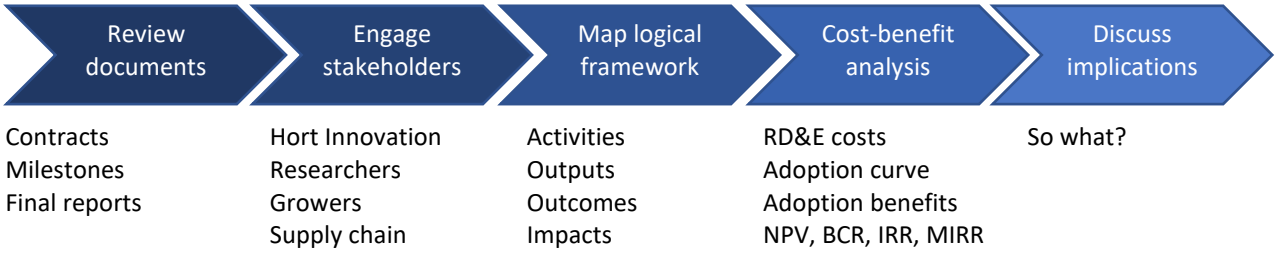
Executive summary

What the report is about

Ag Econ conducted an independent analysis to determine the economic, social, and environmental impact resulting from delivery of the project *MT18019 Development and implementation of protocols to enable importation of improved honey bee genetics to Australia*. The project was funded by Hort Innovation over the period June 2019 to December 2021 using the almond, avocado and melon research and development levies and contributions from the Australian Government.

The analysis applied a five step analytical process to understand the impact pathway and collect supporting data.



Research background

Genetic improvement of honey bee stocks helps to reduce the risk posed by exotic pests and diseases (such as Varroa Mite) and also to support hive productivity more generally. The importation of honey bee germplasm through live queens had not occurred since the Mickleham post entry quarantine (PEQ) facility was commissioned in 2015. Industry beekeepers were not confident in the suitability of the Mickleham facility in both its climate and staff capacity to enable successful queen importations. Similarly, no bee semen importation had been conducted since the release of importation protocols in 2016. Consequently, there was a strong need to trial queen importations through the new quarantine facility and to evaluate the bee semen importation protocol for practicality and biosecurity integrity.

Key findings

The nominal investment cost was $0.37 million. When adjusted for inflation (ABS, 2023) and discounted (using a 5% real discount rate) this came to a 2022-23 present value (PV) of costs equal to $0.47 million.

Through the successful trial importation of bee semen and live queen bees into Australia, MT18019 validated a workable protocol and tested the PEQ facilities for honey bee germplasm imports. This trial provided an important foundation for honey bee industry participants to continue to progress towards the commercial scale importation of genetic material to support the development of a local Varroa-resistant honey bee population.

Through the validated import protocols and procedures, future potential impacts were identified for the almond, avocado and melon industries through a reduced risk of pollination cost increases and productivity losses that otherwise would have been experienced following declines to pollination accessibility and efficiency due to exotic viruses such as the Varroa mite. However, while MT18019 was successful in trialling the importation of honey bee germplasm, discussions with stakeholders identified that a number of subsequent steps were required to realise commercial scale adoption and subsequent impacts.

Project researchers and industry stakeholders commented that the main impediment to leveraging the import protocols established through MT18019 was the difficulty in identifying a reliable source of bee germplasm that is both Varroa-resistant and commercially viable. The focus of the germplasm imported for the project was noted as being for demonstration purposes only and was not necessarily proven to be commercially viable in local conditions. Since the conclusion of MT18019, attempts to import bee semen from New Zealand have been unsuccessful, due to the presence of Deformed Wing Virus being detected in source semen, highlighting the challenges of sourcing clean stock.

An additional impediment identified through the research was a rigorous evaluation of the imported genetics within Australian breeding programs and conditions. The New South Wales based honey bee genetic improvement program *Plan Bee* (funded though AgriFutures), which received five of the third generation queens from the queen importation and which is due to conclude in April 2024, was identified by stakeholders as an important complimentary research program that should provide increased capacity to evaluate the extent of genetic improvements in Australian honey bee populations, supporting a more targeted approach to importing genetics and confirming ongoing breeding and importation priorities. It was also noted that evaluation for retention of the VSH trait in the imported stock is very difficult without direct challenge from Varroa mites. As Varroa mite incursions in New South Wales were still being controlled (destruction of infected hives), industry stakeholders noted that it was difficult to evaluate the performance of hives when faced with Varroa in Australia, or to

maintain the resistant traits in the broader population.

While MT18019 highlighted the logistical viability of importing honey bee genetics, the above ongoing challenges and uncertainties relating to commercial scale importation show that it is too early in the impact pathway for a robust assessment of the MT18019 impact. However, given the foundational contribution of MT18019 to any future commercial importation of honey bee germplasm, any future impact assessment (including of the AgriFutures *Plan Bee* project due for completion in 2024) should consider attributing some impact to MT18019 as part of a cluster or program approach.

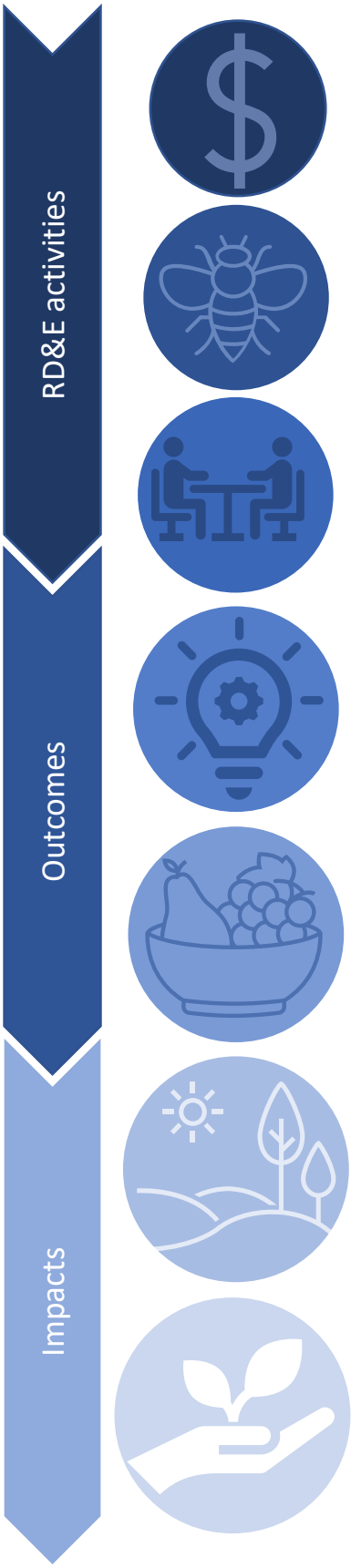
The key findings of the MT18019 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, almond, avocado, melon, pollination security, import, post entry quarantine, varroa mite, biosecurity

Figure 1. Summary of impact assessment findings

MT18019 Protocols for importing honey bee genetics



Total RD&E costs:

- $0.37 million
- 81% R&D levy and Government matching, and 19% CSIRO in-kind.

Research activities:

- Trial the importation of small quantities of honey bee genetic material (semen and queen bees) to validate import protocols and processes.
- Coordinate with Dutch breeding program Arista Bee Research to provide genetic stock with Varroa mite resistant traits.
- Negotiate and revise importation permits with Dutch and Australian authorities.
- Preliminary evaluations of the general performance and hygienic behaviour when crossed with local stock

Extension activities:

- Communicate the biosecure importation framework to industry stakeholders (x2 industry communication updates, x2 presentations, x1 briefing report)

Expected outcomes:

- Improved honey bee industry confidence to undertake commercial-scale importations of bee germplasm (queen bees and bee semen)
- Improved capacity to support bee importation at the Entry Quarantine (PEQ) facility at Mickleham in Victoria.
- Increased diagnostic capability for bee viruses at AgriBio and CSIRO.
- Provide genetic material to breeding evaluation trials *Plan Bee* (funded by Agrifutures) due for completion in 2024.

Industry adoption:

- Bee industry stakeholders are actively working towards commercial scale importation using the identified protocols. However, several constraints remain, including the identification of Varroa-resistant and commercially viable genetic material, and the ongoing evaluation of the imported material including through *Plan Bee* (Agrifutures).

Economic impacts:

- Reduced production cost increases
- Reduced production revenue losses

Social impacts:

- Maintain fresh and affordable domestic horticultural produce
- Increased confidence of sustainable practices

Environmental impacts:

- Avoided chemical use of acaricide and miticide in Varroa risk management.

Total Benefits:

- Quantitative impact assessment was not performed due to the contribution of project deliverables being too early in the impact pathway for reliable assessment.

Introduction

Evaluating the impacts of levy investments is important to demonstrate the economic, social and environmental benefits realised through investment to levy payers, Government and other industry stakeholders. Understanding impact is also an important step to inform the ongoing investment agenda.

Reflecting its commitment to continuous improvement in the delivery of levy funded research, development and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out annually on a representative sample of investments of its RD&E portfolio. Commencing with MT18011 in 2017-18, the impact assessment program consisted of an annual impact assessment of 15 randomly selected Hort Innovation RD&E investments (projects) each year. In line with this ongoing program, Ag Econ was commissioned to deliver the *Horticulture Impact Assessment Program 2020-21 to 2022-23* (MT21015).

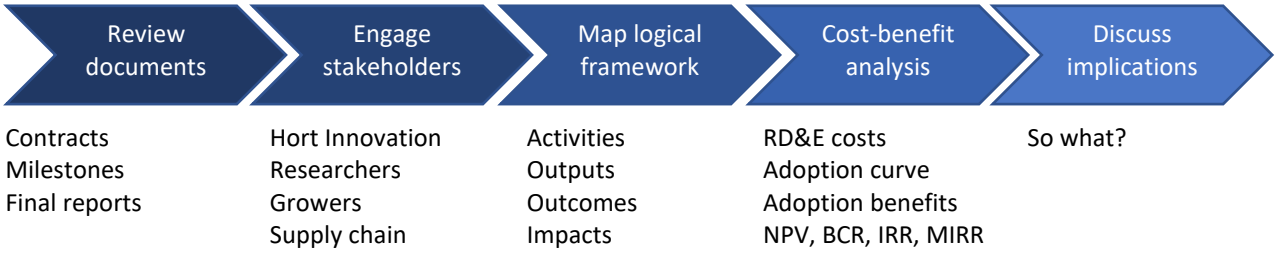
Project *MT18019 Development and implementation of protocols to enable importation of improved honey bee genetics to Australia* was randomly selected as one of the 15 investments in the 2021-22 sample. This report presents the analysis and findings of the project impact assessment.

The report structure starts with the general method of analysis used, followed by the RD&E background and an outline of the impact pathway in a logical framework, then describes the approach used to quantify the identified costs and benefits including any data gaps and limitations to the analysis, presents the results including from the sensitivity analysis, and finally discusses any implications for stakeholders.

General method

The impact assessment built on the impact assessment guidelines of the Council of Rural Research and Development Corporations (CRRDC, 2018) and included both qualitative and quantitative analysis. The general method that informed the impact assessment approach is as follows:

1. Review project documentation including project plan, milestone reports, outputs and final report
2. Discuss the project delivery, adoption and benefits with the Hort Innovation project manager, project researcher/consultant, growers and other relevant stakeholders (see *Stakeholder consultation*)
3. Through a logical framework, qualitatively map the project's impact pathway, including activities, outputs, outcomes to identify the principal economic, environmental, and social impacts realised through the project
4. Collect available data to quantify the impact pathway and estimate the attributable impacts using cost-benefit analysis (over a maximum 30 years with a 5% discount rate), and then sensitivity test the results to changes in key parameters.
5. Discuss the implications for stakeholders.



The analysis identified and quantified (where possible) the direct and spillover impacts arising from the RD&E. The results did not incorporate the distributional effect of changes to economic equilibrium (supply and demand relationships) which was beyond the scope of the MT21015 impact assessment program. A more detailed discussion of the method can be found in the *MT21015 2021-22 Summary Report* on the Hort Innovation project page Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015).

Project background

The Australian honey bee industry provides valuable pollination services to the horticultural sector with many crops totally (almonds, and avocado) or largely (melons) dependent on pollination to achieve fruit/nut set and production yield (Keogh et al. 2010). As such, securing pollination services relies on having healthy and productive honey bee colonies.

European honey bees are the preferred source of pollination for commercial horticulture growers because they are easily

managed in commercial settings and are efficient at pollinating a high number of flowers (Klein et al. 2007). While native bees, flies and other insects are also capable of pollination, they are currently not relied on to support commercial pollination. Initiatives to support ongoing pollination security have therefore become an important priority for these industries, given the dependence on accessing pollinators for supporting production.

The most serious pest of European honey bees, Varroa Mite, infects honey bees in every major beekeeping area of the world, including Australian since the detection of Varroa in New South Wales in July 2022. Varroa Mite is the most significant threat to Australia's pollination security given the existing reliance on European honey bees for providing pollination. Horticulture industries that are highly dependent on pollination have sought to undertake initiatives to support pollination security through RD&E into alternative pollinators (PH16000) and honey bee pest surveillance (MT12011).

Another option to reduce the risk posed by exotic pests (such as Varroa) and diseases (and to support the productivity of the pollination industry more generally) is through the genetic improvement of honey bee stocks. However to do this, the honey bee industry needs a reliable importation process to access the valuable progress made in honey bee breeding programs around the world without introducing harmful pests and pathogens. These advances include traits such as improved production and pollination, resistance to pests and pathogens (e.g. Varroa), and climatic adaptation. Currently two pathways exist in Australia for the introduction of new bee germplasm: grafted larvae from live queens contained in the Post Entry Quarantine (PEQ) facility at Mickleham in Victoria and through drone bee semen.

Importation of honey bee germplasm through live queens had not occurred since the Mickleham PEQ facility was commissioned in 2015. Industry beekeepers were not confident in the suitability of the Mickleham facility in both its climate and staff capacity to enable successful queen importations. Similarly, no bee semen importation had been conducted since the release of importation protocols in 2016. Consequently, there was a strong need to trial queen importations through the new quarantine facility and to evaluate the bee semen importation protocol for practicality and biosecurity integrity.

Project MT18019 emerged from conversations between multiple industry participants, the Australian Honey Bee Industry Council , the Australian Queen Bee Breeders Association , the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Department of Agriculture, Water and Environment (DAWE), the Wheen Bee Foundation and Hort Innovation. The project aimed to assess the importation protocols and procedures for both queens and semen to successfully introduce honey bee genetics selected for resistance to the Varroa mite. Establishing Varroa mite resistance in Australia's honey bee population can help prepare for a future invasion of this pest and minimize its impact on pollination services for horticulture.

With a focus on supporting processes to establish Varroa mite resistance in Australia's honey bee population and minimising its impact on pollination services for horticulture in the case of an outbreak across Australia, MT18019 was closely aligned to Outcome 2 of the 2017-2021 Almond Strategic Investment Plan (SIP): *A major productivity gain in almond pollination by 2022 through a 25 per cent reduction in bee stocking rates with no loss in pollination efficiency (nut set)*. Outcomes in the Avocado and Melon SIPs aligning to the objectives of MT18019 were not identified.

Project details

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) was selected as the lead delivery partner and was supported by Bee Scientifics, with the project running from 2019 to 2021 (Table 1)

Table 1. Project details

Project code	MT18019
Title	Development and implementation of protocols to enable importation of improved honey bee genetics to Australia
Research organization(s)	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Bee Scientifics
Project leader	Dr John Roberts
Funding period	June 2019 – December 2021
Objective	Develop a logistical framework to guide future honey bee importations to support the future establishment of a Varroa resistant honey bee population

Logical framework

The impact pathway linking the project's activities and outputs, and their assessed outcomes and impacts have been laid out in a logical framework, summarised visually in Figure 1, with full detail in Table 2.

Table 2. Project logical framework detail

RD&E activities	 	• Importation protocols and logistics for queen bee and bee semen imports were trialled through:
		  ○ Domestic trial of "importing" queen bees through the Mickleham PEQ facility.
		  ○ Identifying desirable overseas sources of queen bee and bee semen stock
		  ○ Establishing relationships with Dutch breeding program Arista Bee Research to provide stock selected for Varroa resistant traits (Varroa Sensitive Hygiene (VSH)).
		  ○ Submitting import permit application for germplasm (honey bee semen and queens) to DAWR and discussing the practicalities of compliance.
		  ○ Negotiating import permits and health certificates with Dutch authorities
		  ○ Importing a small quantity of bee semen from the Netherlands in 2020 in line with DAWR's import conditions:
		  ○ Test the sample for viruses prior to importation.
		  ○ Test sample for Africanised genetics and viruses in Australia at AgriBio in Victoria and CSIRO (first sample only, with insufficient volume in the second sample).
		  ○ After importation, artificially inseminate four virgin Australian queens.
		  ○ Importing live queens from the Netherlands, aligned to DAWR's import conditions:
		  ○ Negotiate with DAWE and Dutch authorities variations to import permit requirements and health certificate for live queen bees, including pre-export testing for Africanised genetics.
		  ○ Import two live queens with worker bee escorts, and screen for viruses.
		  ○ Introduce the surviving queento a nucleus colony in a PEQ flight cage.
		  ○ Establish hives with artificial insemination from domestic drone semen, and test progeny of established gives for exotic viruses.
		  ○ Crossing stock from the imported bee semen and live queen import with Australian stock and evaluate general performance and hygienic behaviour.
		  ○ Delays throughout the project reduced the time available for stock evaluation, particularly relating to evaluation of queen bee imported stock. However, hybrid stock from the semen importation in August 2020 was evaluated over approximately one year for general performance through comparison with quality Australian stock under the same apiary conditions. This stock showed comparably strong brood and honey production and demonstrated good temperament.

RD&E outputs		• A logistical framework for importing honey bee germplasm into Australia developed from the experience of the bee semen and live queen import trial. • Variations to the import permits and health certificates that align the requirements of Australian and export country authority expectations. • A small quantity of Varroa resistant honey bee genetic stock was imported. • Three queens inseminated with imported bee semen, producing 58 second generation queens, and 5 third generation queens. All stock were in Victoria at the end of the project. • From two imported queen bees, one second generation queen was produced, and 100 third generation queens. Third generation queens were sent to breeding programs in Queensland (8), New South Wales (5), and Victoria (87). • Industry extension material developed that outlines the biosecure importation framework (x2 industry communication updates, x2 presentations, x1 briefing report).

Outcomes		• The honey bee industry participants have a tested framework for importing honey bee genetics that minimizes biosecurity risks, increasing the industry's confidence to undertake future importations. • The PEQ Mickleham has improved capacity to support bee germplasm importations through an knowledge experience of quarantine workflow and avenues for optimization. • Increased diagnostic capability for bee viruses and Africanised bees at AgriBio Victoria and CSIRO. • New knowledge of the general performance, virus transmission and trait retention of Varroa resistant stock in Australian conditions. It was noted that evaluation for retention of the VSH trait in the imported stock is very difficult without direct challenge with Varroa mites. The only method available for this project was a freeze-kill brood test to determine the level of general hygienic behaviour of hybrid colonies, which can correlate with VSH. The testing results showed that hybrid colonies displayed high general hygienic behaviour. Further evaluation for VSH trait retention would require improved field bioassays that more closely replicate Varroa infestation or require imported stock to be returned overseas for direct assessment against Varroa mites.
Impacts		• Increased industry capacity and confidence to import honey bee germplasm, supporting increased pollination security for industries reliant on pollination services: ○ [Economic] Reduced biosecurity risk for the pollination services industry, including a reduction in biosecurity management costs relating to surveillance, containment, and eradication (including the loss or destruction of bee populations). ○ [Economic] Reduced risk of cost increases and revenue losses for pollination reliant industries, including from the reduced availability and higher cost basis for pollination services, and reduced plant yield and quality from reduced pollination services. ○ [Socio-economic] Reduced risk to regional communities that are reliant on horticulture industries as an important source of employment and economic stimulant (The CIE 2023). ○ [Socio-economic] Reduced health and wellbeing costs to farm staff including psychological stress and strains on business and community relationships related to honey bee biosecurity events (CSIRO 2020 and CSIRO 2021). ○ [Socio-economic] Reduced risk of disruption to the supply of fresh and affordable domestic horticultural produce, thereby supporting ongoing fruit, nut and vegetable consumption with associated health and wellbeing benefits (Angelino et al 2019, Mujcic et al 2016, Hort Innovation 2020). ○ [Environmental] Reduced risk of environmental impacts associated with the use of acaricide and miticide to manage the spread of Varroa mite in paid pollination services such as amitraz and pyrethroids, which are common Varroa mite controls (Jack and Ellis 2021) and which are highly toxic to a wide range of insects including bees, butterflies, bugs and beetles (CRDC 2023 and Australian Gov. 2021)

Project costs

The project was funded by Hort Innovation, using the almond, avocado and melon research and development levy and contributions from the Australian Government, with additional funding from research partners CSIRO (Table 3). Where relevant, overhead costs were added to the direct project cost to capture the full value of the RD&E investment.

Nominal investment

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs ($)	Hort Innovation overheads[1] ($)	CSIRO In-Kind[2]	Total nominal ($)
2019	100,000	20,986	28,231	149,217
2020	70,000	12,245	19,762	102,007
2021	42,500	7,078	11,998	61,576
2022	37,500	6,014	10,587	54,101
Total	**250,000**	**46,323**	**70,578**	**366,901**

1. The overhead and administrative costs were calculated from the Statement of Comprehensive Income in the Almond, Avocado and Melon Industry's Fund Annual Report 2018-19 to 2021-22, averaging 17.8% for the MT18019 funding period (2019-2022). 2. Other funds from CSIRO are provided in the contract as a lump sum, so have been apportioned yearly based on Hort Innovation cash costs.

Present Value of investment

The nominal total investment cost of $0.37 million identified in Table 3 was adjusted for inflation (ABS, 2023) into a real investment of $0.42 million (2022-23 equivalent values). This was then further adjusted to reflect the time value of money using a real discount rate of 5% (CRRDC 2018), generating a present value (PV) of costs equal to $0.49 million (2022-23 PV).

Project impacts

The impact pathways identified in Table 2 was evaluated against available data to determine if their impact could be quantified with a suitable level of confidence.

While MT18019 was successful in trialling the importation of honey bee germplasm, discussions with stakeholders identified that a number of subsequent steps were required to realise commercial scale adoption and subsequent impacts.

Project researchers and industry stakeholders commented that the main impediment to leveraging the import protocols established through MT18019 was the difficulty in identifying a reliable source of bee germplasm that is both Varroa-resistant and commercially viable. The focus of the germplasm imported for the project was noted as being for demonstration purposes only and was not considered to have generated an impact itself. Since the conclusion of MT18019, attempts to import bee semen from New Zealand have been unsuccessful, due to the presence of Deformed Wing Virus being detected in source semen, highlighting the challenges of sourcing clean stock.

An additional impediment identified through the research was a rigorous evaluation of the imported genetics within Australian breeding programs and conditions. The New South Wales based honey bee genetic improvement program *Plan Bee* (funded though AgriFutures), which received five of the third-generation queens from the queen importation and which is due to conclude in April 2024, was identified by stakeholders as an important complimentary research program that should provide increased capacity to evaluate the extent of genetic improvements in Australian honey bee populations, supporting a more targeted approach to importing genetics and confirming ongoing breeding priorities.

It was also noted that evaluation for retention of the VSH trait in the imported stock is very difficult without direct challenge from Varroa mites. As Varroa mite incursions in New South Wales were still being controlled (destruction of infected hives) at the time of analysis, industry stakeholders noted that it was difficult to evaluate the performance of hives when faced with Varroa in Australia, or to maintain the resistant traits in the broader population.

While MT18019 highlighted the logistical viability of importing honey bee genetics, the above challenges and uncertainties relating to the potential for commercial scale importation mean that the potential social, economic, and environmental impacts identified in the Logical Framework (Table 2) could not be quantified with any confidence at this time.

Conclusions

Due to the ongoing challenges and uncertainties relating to the potential for commercial scale importation meant it was assessed as being too early in the impact pathway for a robust assessment of the MT18019 impact. However, given the foundational contribution of MT18019 to any future commercial importation of honey bee germplasm, any future impact assessment (including of the AgriFutures *Plan Bee* project due for completion in 2024) should consider attributing some impact to MT18019 as part of a cluster or program approach.

Stakeholder consultation

Where possible, Ag Econ sought to engage multiple stakeholders across key areas of the logical framework and impact pathway to augment existing information and data sources, and reduce any uncertainty or bias from individual stakeholders. All stakeholders were engaged through telephone or online meetings, with follow up emails as necessary. Consultation followed a semi-structured approach in line with broad topics relating to the impact pathway and associated data requirements. Table 6 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 6. Stakeholder consultation by theme

Stakeholder details		Consultation topics						
Stakeholder and organisation	**Stakeholder type**	**Related research**	**Research inputs**	**Research outputs**	**Research immediate outcomes**	**Follow on research**	**Stakeholder adoption**	**Impact areas and data**
Ashley Zamek, Hort Innovation IPDM R&D Manager	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Dr John Roberts, CSIRO	RD&E practitioner	✓	✓	✓	✓	✓	✓	✓
Jody Gerdts, Bee Scientifics	RD&E practitioner	✓	✓	✓	✓	✓	✓	✓
Danny Le Feuvre, Australian Honey Bee Industry Council	RD&E Stakeholder	✓			✓	✓	✓	✓
Fiona Chambers, Wheen Bee Foundation	RD&E Stakeholder				✓	✓	✓	✓
Peter Czeti, Queen Bee Breeders Association	RD&E Stakeholder				✓	✓	✓	✓

Glossary of economic terms

Benefit-cost ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Cost-benefit analysis (CBA)	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Direct Effects	Impacts generated for the funding industry as a result of adoption of the RD&E outputs and recommendations, typically farm level outcomes relating to productivity and risk.
Discounting and Present Values	The process of relating the costs and benefits of an investment to a base year to reflect the time value of money or opportunity cost of RD&E investment. The analysis applies a real discount rate of 5% in line with CRRDC Guidelines (CRRDC 2018).
Economic Equilibrium	Due to a market's underlying supply and demand curves, changes in supply will have an impact on price and vice-versa. The Economic Equilibrium is the point at which market supply and price are balanced. Estimating the magnitude of market response to changes in supply or demand is a complex and demanding task that is considered beyond the scope of most CRRDC Impact Assessments (CRRDC 2018).
Internal rate of return (IRR)	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Modified internal rate of return (MIRR)	The internal rate of return of an investment that is modified so that the cash inflows generated from an investment are re-invested at the rate of the cost of capital (in this case the discount rate).
Net present value (NPV)	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Nominal and real values	Nominal values reflect the actual values in a given year (e.g. contracted RD&E expenses). These are converted to real (inflation adjusted) values to make them comparable across time.
Spillover Effects	Impacts generated for stakeholders who did not fund the RD&E, including other agricultural industries, consumers, communities, and the environment.

Abbreviations

CRRDC Council of Rural Research and Development Corporations

CSIRO The Commonwealth Scientific and Industrial Research Organisation

DAWE Australian Government Department of Agriculture, Water and Environment (Department of Agriculture, Fisheries and Forestry from 2022)

IPDM Integrated Pest and Disease Management

PEQ Post Entry Quarantine

RD&E Research, Development and Extension

SIP Strategic Investment Plan

VSH Varroa Sensitive Hygiene, a trait associated with Varroa Mite resistance

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