1/6/2026

Estimating the contribution of feral honey bees to crop pollination in Tasmania

Dr Jonathan Finch, Dr Ryan Warren and Dr Justin Cappadonna
Tasmanian Institute of Agriculture, University of Tasmania

Executive Summary

Honey bees provide important pollination services to Tasmanian horticulture and vegetable seed industries. These services are supplied by both managed hives placed by beekeepers and by unmanaged background pollination, which may include feral honey bee colonies, spill-over from nearby managed hives and other insects. Feral honey bees are of particular concern because they are not actively treated for *Varroa destructor* and are expected to decline substantially if Varroa becomes established in Tasmania.

This project used grower-reported hive stocking rates to estimate the likely reliance of key Tasmanian crops on managed and background pollination services. This indirect approach provides a practical way to estimate reliance on feral honey bees and other background pollination services without requiring exhaustive field surveys of pollinator visitation across all crops and regions. Fruit and berry survey responses covered 64 crop-level records and 1,477 ha of production across apple, cherry, strawberry, blueberry, raspberry and blackberry crops. Vegetable seed data covered eight crop/company-level records representing 140 fields and 1,132 ha of production.

Two distinct pollination-risk pathways were identified. First, apples showed the strongest evidence of reliance on feral honey bees and other background pollination services. Apple growers reported a mean stocking rate of 0.67 hives/ha, equivalent to approximately 20% of the benchmark mean, with 9 of 14 reporting no managed hives. This pattern was especially evident in the Huon Valley, where 12 of the 14 surveyed apple growers were located, yet only two reported using managed hives.

Vegetable seed production appears to be a major user of managed hives in Tasmania. Seed crops represented an estimated 10,930 crop-level hive placements across the season, with carrot seed alone accounting for approximately 9,200 hive placements.

Overall, the findings suggest that Varroa risk is likely to vary by crop and production system. Some crops may be vulnerable to the loss of feral honey bees and other background pollination services, while others may be vulnerable through increased pressure on managed hive supply, quality and cost.

1. Background

Pollination-dependent crops make an important contribution to the Tasmanian economy. The Tasmanian fruit sector had an estimated farmgate value of $401 million in 2023-24 (Tasmania, 2024), while combined berry production in Tasmania was valued at approximately $216 million as of June 2024. The Tasmanian vegetable and pasture seed industry had a farmgate value of $48 million in 2022-23, with vegetable seed production including crops such as carrot, beetroot and brassica seed (Tasmania, 2024). Together, these figures highlight the economic importance of maintaining reliable pollination services for fruit, berry and seed production in Tasmania.

European honey bees (*Apis mellifera*) are the dominant crop pollinators in many Tasmanian horticultural systems (Prendergast et al., 2021, Hanusch et al., 2025), supporting the production of apples, cherries, berries, vegetable seed and other pollination-dependent crops. These pollination services are provided by a combination of managed hives placed by beekeepers and “background pollination” from unmanaged sources. In this report, background pollination refers to pollination that occurs without managed hives being deliberately placed in the crop and may include feral honey bee colonies, spill-over from nearby managed hives, and other unmanaged insect pollinators.

A key uncertainty for Tasmania is the current density and distribution of feral honey bee colonies. While managed hive numbers can be estimated through industry and registration data, feral colonies are much harder to quantify because reliable estimates require direct detection of colonies, often in tree hollows. Mainland Australian studies show that feral colony densities can vary widely, from very low densities in some agricultural landscapes to high densities in fragmented eucalypt woodland, including estimates around 69 colonies per km² in one study (Hinson et al., 2015). No equivalent systematic estimate exists for Tasmania. This creates an important knowledge gap because feral honey bees may currently provide an unmeasured component of crop pollination services.

The arrival and spread of *Varroa destructor* (henceforth Varroa) on mainland Australia has created a major biosecurity concern for Tasmania. International experience shows that Varroa can cause large declines in feral honey bee populations, while managed colonies can only be maintained through active monitoring and treatment (Chapman et al., 2023 May 24, Traynor et al., 2020). If Varroa becomes established in Tasmania, the loss of feral colonies could reduce background pollination services and increase the need for managed hives.

At present, the contribution of feral honey bees to Tasmanian crop pollination is poorly quantified. This creates uncertainty for growers and industry planners because some crops may already be receiving important pollination services from feral bees or from other background pollination sources. For example, where growers do not routinely introduce managed hives but still achieve commercial production, this may indicate reliance on feral honey bees, managed hive spill-over from nearby crops, or other unmanaged insects.

Vegetable seed production adds a second dimension to this risk. Many seed crops require high levels of insect pollination to achieve commercial seed yields. In these systems, pollination is directly linked to the harvested product, and production may already depend heavily on managed hive placement. For these crops, the main Varroa-related risk may not be the direct loss of feral bee pollination, but reduced managed hive availability, increased hive costs and the need to maintain strong, healthy colonies.

This project aimed to estimate the likely contribution of feral honey bees and other background pollination services to pollination in key Tasmanian crops by documenting grower hive-stocking practices and comparing these with published stocking-rate benchmarks. This provides a practical, scalable method for identifying crops and regions where background pollination services may be important, without requiring exhaustive surveys of pollinator visitation or direct identification of the origin of individual honey bees.

2. Methods

This project used a grower survey approach to document current honey bee hive-stocking practices in key pollination-dependent crops in Tasmania. The fruit and berry component focused on crops where honey bee pollination is known to be important, including apples, cherries, blueberries, strawberries, raspberries and blackberries.

Growers were contacted through industry networks and invited to provide information about their crop type, approximate production area, and the number of managed honey bee hives used during flowering. Where relevant, growers also provided comments on pollination practices, perceived reliance on managed hives, and whether hives were routinely introduced each season.

Hive-stocking rates were calculated as the number of managed hives used per hectare of crop. These values were summarised by crop type and compared with published hive-stocking recommendations from Australian and international industry and extension sources. Where published recommendations were presented as ranges, the midpoint of each range was used to calculate crop-level summary statistics.

Published hive-stocking recommendations were treated as indicative benchmark values. It is important to note that these values are not necessarily independent estimates. Some recommendations may be repeated across extension publications or derived from the same original source material. Therefore, benchmark means and standard deviations should be interpreted as summaries of available published recommendations rather than statistically independent estimates of crop-specific hive requirements.

The comparison between reported Tasmanian hive-stocking rates and published benchmark values was used to infer the likely contribution of background pollination services, including feral honey bees and possible spill-over from nearby managed hives. In particular, crops with low or zero managed hive stocking were considered likely to receive some level of pollination from unmanaged or background sources.

Vegetable seed data were provided by two major Tasmanian seed companies. These companies use consistent hive-stocking rates across multiple farms and fields, meaning the dataset differs from the fruit-sector survey data. In the seed dataset, each record represents a crop/company-level stocking rate rather than an individual grower or farm. The dataset included crop type, total crop area, hives per hectare and number of fields represented. Estimated hive placements were calculated by multiplying crop area by the reported hive-stocking rate.

Seed-sector hive-stocking rates were summarised by crop and compared with published benchmark values for carrot, onion and brassica seed crops. Celery and parsnip were included in the grower dataset but were not compared with benchmark values because suitable benchmark datasets were not compiled at this stage.

All grower and company data were de-identified prior to analysis. Results are reported in aggregated form only, and no individual growers, farms or companies are identified.

3. Results

3.1 Summary of benchmark data for fruit and berry crops

Published hive-stocking recommendations varied substantially among fruit and berry crops (Table 1). Strawberry and blueberry generally had the highest benchmark values, while apple and cherry recommendations were lower. Raspberry and blackberry recommendations were variable, with some sources suggesting relatively low stocking rates and others recommending much higher levels, particularly for blackberry.

Table 1. Summary of published benchmark hive-stocking rates used for fruit and berry crop comparison. Note: Benchmark records were compiled from published industry and extension sources. Where a source provided a range, the midpoint was used for calculation of the mean and standard deviation.

Crop	Benchmark records (n)	Mean benchmark stocking rate (hives/ha)	Standard deviation	Benchmark range (hives/ha)
Apple	6	3.5	2.2	1-12
Cherry	7	4.6	2.7	1-14
Strawberry	6	13.8	5.5	1.2-25
Blueberry	10	9.5	3.8	1-20
Raspberry	4	4.0	3.0	0.5-10
Blackberry	3	6.4	4.5	2-14

3.2 Tasmanian fruit and berry grower data

The fruit and berry survey dataset (Table 2) comprised 64 crop-level records representing 1,477 ha of crop production. The largest surveyed crop areas were cherry (512 ha), apple (417 ha), raspberry (192 ha), blueberry (159 ha), strawberry (132 ha), and blackberry (66 ha).

Reported managed hive-stocking rates varied strongly among crops. Apple growers reported the lowest use of managed hives, with a mean stocking rate of 0.67 hives/ha. By contrast, all cherry, blueberry and blackberry records reported some managed hive use. Raspberry and strawberry showed intermediate patterns, with most but not all growers reporting managed hive placement.

Table 2. Summary of Tasmanian grower-reported hive-stocking data for fruit and berry crops.

Crop	Records	Total area surveyed (ha)	Mean hives/ha	SD hives/ha	Range hives/ha	% using managed hives
Apple	14	417.0	0.67	1.00	0.00-2.60	35.7%
Blackberry	3	65.9	5.00	1.00	4.00-6.00	100%
Blueberry	10	158.8	6.82	3.84	1.33-15.00	100%
Cherry	16	512.1	4.30	3.30	1.88-16.00	100%
Raspberry	11	191.7	5.53	2.56	0.00-10.00	90.9%
Strawberry	10	131.6	1.93	2.37	0.00-8.00	70.0%

3.3 Fruit and berry comparison with benchmarks

Comparison with published benchmark stocking rates showed strong crop-specific differences (Table 3). Apple and strawberry had the lowest reported managed hive stocking rates relative to published benchmarks. Apple growers reported a mean stocking rate of 0.67 hives/ha, equivalent to approximately 20% of the benchmark mean. Strawberry growers reported a mean stocking rate of 1.93 hives/ha, equivalent to approximately 14% of the benchmark mean.

Table 3. Comparison of Tasmanian reported hive-stocking rates with benchmark values for fruit and berry crops.

Crop	Records	Mean Tasmanian hives/ha	Benchmark hives/ha	Tasmanian rate as % of benchmark	Records below benchmark
Apple	14	0.67	3.5	19.2%	14 / 14
Blackberry	3	5.00	5.0	100.0%	1 / 3
Blueberry	10	6.82	9.5	71.8%	8 / 10
Cherry	16	4.30	4.6	93.5%	13 / 16
Raspberry	11	5.53	5.0	110.6%	4 / 11
Strawberry	10	1.93	13.8	14.0%	10 / 10

Apple was notable for both low mean stocking rates and frequent absence of managed hives. Nine of 14 apple records reported no managed hives during flowering. This pattern was especially evident in the Huon Valley, where 12 of the 14 surveyed apple growers were located and only 2 of these 12 growers reported using managed hives. This suggests that apple production in this region may currently receive substantial background pollination services, potentially including feral honey bees, spill-over from nearby managed hives, and other unmanaged pollinators.

Strawberry also had low managed hive stocking relative to published benchmarks. This result should be interpreted cautiously because strawberry pollination recommendations vary widely, and some Tasmanian strawberry systems may differ from the production systems on which published benchmarks are based. Nevertheless, the low reported stocking rate suggests that background pollination or production-system differences may be important.

Cherry, blueberry, raspberry and blackberry were more consistently stocked with managed hives. All cherry, blueberry and blackberry records reported some managed hive use, although many individual records were still below benchmark values. Raspberry and blackberry reported mean stocking rates close to or above benchmark values, suggesting more consistent reliance on managed hive placement in these crops.

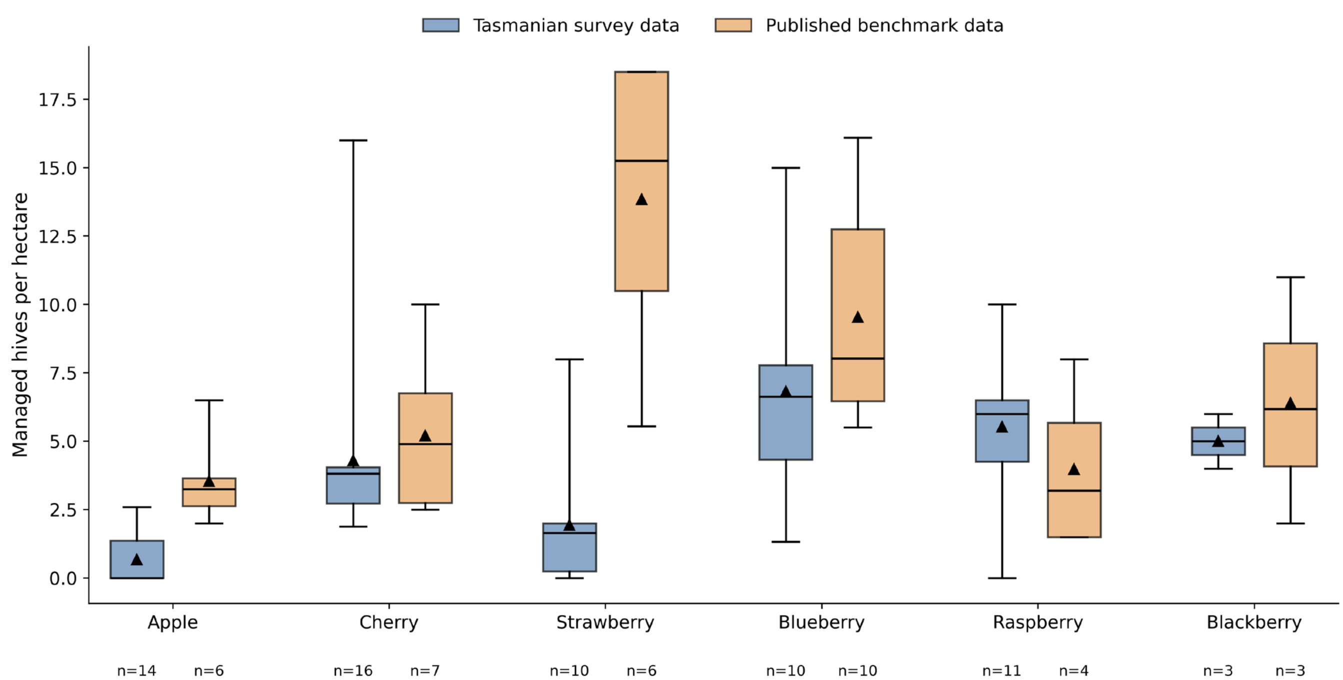

Figure 1. Box-and-whisker plots comparing Tasmanian grower-reported managed hive stocking rates with published benchmark stocking rates for major fruit and berry crops. Boxes show the interquartile range, horizontal lines show the median, triangles show the mean, and whiskers show the full observed range.

3.4 Vegetable seed industry data

The seed-industry dataset comprised eight crop/company-level records representing 140 fields and 1,132 ha of production (Table 4). These records represented an estimated 10,930 crop-level hive placements across the season. Because the data were provided at the crop/company level rather than the individual farm level, the number of fields and total crop area are more informative than the number of records.

Carrot seed accounted for most of the estimated hive placements, with 920 ha across 73 fields and an estimated 9,200 hive placements. Brassica seed was the second-largest contributor, representing 195 ha across 61 fields and an estimated 1,560 hive placements. Smaller areas of onion, parsnip and celery seed were also included.

Table 4. Summary of Tasmanian vegetable seed hive-stocking data.

Crop	Fields	Area represented (ha)	Estimated hive placements	Mean hives/ha
Brassica	61	195.0	1,560	8.0
Carrot	73	920.0	9,200	10.0
Celery	1	0.4	4	10.0
Onion	4	15.0	146	9.0
Parsnip	1	2.0	20	10.0

Carrot seed production dominated estimated hive use in the seed dataset, accounting for approximately 84% of the estimated managed hive placements represented (Table 5). Brassica seed was the second-largest user, accounting for approximately 14%. This result highlights the importance of carrot seed production as a major user of managed pollination services. Even though the dataset contains only two carrot records, these records represent 73 fields and 920 ha of production.

Table 5. Contribution of each seed crop to estimated managed hive use.

Crop	Estimated hive placements	% of seed-sector hive use
Carrot	9,200	84.2%
Brassica	1,560	14.3%
Onion	146	1.3%
Parsnip	20	0.2%
Celery	4	<0.1%

3.5 Vegetable seed comparison with benchmarks

Benchmark values varied among seed crops (Table 6). Carrot seed benchmark values were generally high, commonly around 5-10 hives/ha. Onion seed had the highest and most variable benchmark values, with some sources recommending substantially higher rates up to 30 hives/ha. Brassica benchmark values were lower, generally around 3-6 hives/ha depending on the crop and source. National industry data also identify carrot seed and cauliflower seed as crops requiring high hive stocking rates.

Table 6. Summary of benchmark hive-stocking rates used for seed crop comparison. Note: Where sources provided a range, the midpoint was used for summary calculations.

Crop	Benchmark records (n)	Mean benchmark hives/ha	SD	Benchmark range (hives/ha)
Carrot	6	7.3	1.7	5.0-10.0
Onion	4	24.5	6.1	16.0-30.0
Brassica	3	4.3	0.3	4.0-4.5

Carrot and brassica seed crops were stocked above benchmark means (Table 7). Carrot seed was stocked at 10 hives/ha, compared with a benchmark mean of approximately 7.3 hives/ha. Brassica seed was stocked at 8 hives/ha, compared with a benchmark mean of approximately 4.3 hives/ha. Onion seed was stocked below the benchmark mean, although onion benchmark values were highly variable and included very high recommendations from some sources.

Table 7. Comparison of Tasmanian seed-sector stocking rates with benchmark values.

Crop	Area represented (ha)	Grower mean hives/ha	Benchmark records	Benchmark mean hives/ha	Grower rate as % of benchmark
Carrot	920.0	10.0	6	7.3	137.9%
Onion	15.0	9.0	4	24.5	39.7%
Brassica	195.0	8.0	3	4.3	184.6%

The comparison suggests that carrot and brassica seed production in Tasmania are already stocked heavily relative to available published benchmarks. Onion seed appears to be stocked below benchmark values, but this should be interpreted cautiously because onion benchmarks vary widely (Table 6) and may reflect different production systems, hybrid seed contexts or overseas conditions.

4. Discussion

A useful outcome of this study is the demonstration of a practical indirect method for assessing reliance on background pollination. Directly measuring the contribution of feral honey bees is difficult because managed and feral honey bees are visually indistinguishable in the field and may forage over overlapping areas. By comparing grower-reported managed hive stocking rates with published benchmark recommendations, it is possible to identify crops where current managed hive use appears insufficient to explain expected pollination requirements. These gaps do not prove feral bee contribution directly, but they provide a useful indicator of where background pollination services are likely to be important and where more detailed field studies should be prioritized.

The clearest evidence for reliance on background pollination was observed in apples. Across surveyed apple records, managed hives placed directly in apple orchards represented approximately 20% of the published benchmark stocking rate. This suggests that background pollination services may be making a substantial contribution to apple pollination in Tasmania.

The low rate of hive use was especially evident in the Huon Valley, where most surveyed apple growers were located and many reported no managed hives placed directly in apple blocks. In these orchards, pollination appears to be supplied largely by background sources, which may include feral honey bees, managed hives placed in nearby crops, and other unmanaged pollinators. The present method cannot distinguish between these sources. If Varroa becomes established and feral honey bee populations decline, Huon Valley apple growers may therefore be relatively exposed to changes in background pollination availability.

Strawberries also showed low managed hive stocking relative to benchmark values, although this result is more difficult to interpret. Published strawberry stocking recommendations vary widely, and the need for managed hives may differ between open-field, tunnel-grown and more enclosed production systems. In addition, strawberry crops in Tasmania often receive a high proportion of flower visits from non-bee insects, particularly flies (Finch, unpublished data). These factors may contribute to the discrepancy between published honey bee stocking benchmarks and actual grower stocking rates, although the pollination effectiveness of these visitors remains uncertain.

Cherry, blueberry, blackberry and raspberry crops were more consistently stocked with managed hives near the benchmarked rates. These crops may therefore be less exposed to the direct loss of feral honey bee pollination than apples. However, this does not mean they are unaffected by Varroa. Their vulnerability is more likely to arise through increased hive management costs, reduced hive availability and competition with co-flowering crops (i.e. carrots). In addition, cherries and blueberries are often grown under bird netting, which may limit access by feral honey bees and other wild pollinators, increasing the importance of managed hives within those systems.

The vegetable seed sector represents a distinct pollination-risk category. Unlike apples, where low managed hive placement suggests reliance on background pollination services, vegetable seed crops appear to be major users of managed hives. The current dataset represented an estimated 10,930 crop-level hive placements across 1,132 ha and 140 fields. This was driven primarily by carrot seed production, which accounted for approximately 84% of estimated seed-sector hive placements.

For vegetable seed crops, the main Varroa-related risk is likely to be reduced hive availability, increased hive costs and hive-quality issues, rather than direct loss of background pollination. This is particularly important because seed crops are grown specifically for seed set, meaning that pollination is directly linked to the harvested product. If managed hive supply becomes constrained under Varroa, the seed sector may face increased competition for hives during flowering periods.

Carrot and brassica seed crops were stocked above benchmark means, suggesting that Tasmanian seed producers are already using high managed hive densities. This may reflect the importance of pollination for seed yield, the relative unattractiveness of some seed crops to honey bees (Quarrell et al., 2023), or the need to ensure adequate pollen movement across male and female parental lines in hybrid seed production. Onion seed was stocked below benchmark values, but this result should be interpreted cautiously because onion benchmarks were highly variable and may reflect different production systems or international contexts.

Several caveats should be considered to our study. First, hives are not all equal. Published recommendations often report "hives per hectare" without accounting for colony strength, hive size, bee numbers, brood area, forager activity or colony health. A small or weak hive may provide much less pollination service than a strong hive, even when counted equally (Ramírez-Mejía et al., 2024).

Second, crops are not always spatially independent. Co-flowering apple and cherry blocks often occur near one another on the same farm or within the same district, and hives placed for one crop may contribute to pollination in another. Therefore, the absence of hives placed directly in a crop does not necessarily mean that the crop receives no managed honey bee visitation. This is likely to be the case in the Huon Valley, where hives are often added to cherry blocks in spring whilst apples also flower nearby.

Third, production systems differ in how accessible they are to background pollinators. Cherries and blueberries are often grown under bird netting, which may limit access by feral honey bees and other wild pollinators (Sonter et al., 2024). Raspberries and strawberries are often grown in tunnels, although these are usually not fully enclosed. Vegetable seed crops may also differ in attractiveness to honey bees, crop layout and the need for pollen transfer between parental lines.

Fourth, published benchmark values should be interpreted cautiously. Many hive-stocking recommendations are based on extension advice, grower experience, or older literature rather than controlled experiments. Some values may also be repeated across extension guides or derived from the same original source material. As a result, the benchmark means and standard deviations used here should be interpreted as practical summaries of commonly cited recommendations rather than precise meta-analytic estimates.

Despite these limitations, the results provide a useful first estimate of where Tasmanian crops may be most dependent on background pollination services and where they may be most dependent on managed hive supply. Apples, particularly in the Huon Valley, appear to be the clearest priority for further investigation of background pollination dependence. Vegetable seed production, particularly carrot seed, appears to be a major priority for assessing managed hive demand and hive availability under Varroa.

Tasmania’s pollination system is highly dependent on honey bees, including both managed colonies and an unknown number of feral colonies. If Varroa and associated viruses substantially reduce feral honey bee populations, the impact may be difficult to predict because the baseline density and distribution of these colonies is not currently known.

Alternative pollinators may provide some buffering capacity, but this is likely to vary strongly by crop. Bumble bees are the main alternative pollinator in Tasmania and are not expected to be directly affected by Varroa. However, several studies have shown that bumble bees account for only a small proportion of visits in many crops, although their contribution may be much higher in blueberries (Prendergast et al., 2021, Hanusch et al., 2025). This means that bumble bees may provide useful resilience in some systems but are unlikely to fully replace honey bee pollination across the broader horticultural sector.

International experience shows that apiculture industries can persist in regions where Varroa is established, but usually through adaptation rather than simple continuation of existing practices. In some jurisdictions, managed bumble bee hives and other pollination options help reduce reliance on honey bees (Levesque et al., 2025). Tasmania has fewer alternative commercial pollination options, which increases the importance of preparedness, modelling, surveillance, and better estimates of feral honey bee abundance. The data generated in this project therefore provide important inputs for understanding where pollination shortfalls may emerge if honey bee numbers decline.

Overall, the findings support the need for continued pollination risk assessment in Tasmania. If Varroa becomes established and feral honey bee populations decline, the effects on crop pollination are likely to vary by crop, region and production system. Crops currently receiving significant background pollination services may experience increased vulnerability, while crops already reliant on managed hives may be affected through increased hive demand, higher pollination costs and potential limits in hive availability.

5. Conclusions

Grower-reported hive-stocking data indicate that managed hive use varies widely among Tasmanian pollination-dependent crops. Apple production showed the strongest evidence of reliance on background pollination services, with many growers reporting no managed hive placement during flowering. This pattern was especially evident in the Huon Valley. Strawberry also showed low managed hive use relative to benchmark recommendations, although interpretation is complicated by variation in production systems and benchmark values.

Vegetable seed production showed a different risk profile. The seed dataset represented 140 fields, 1,132 ha of production and an estimated 10,930 crop-level hive placements across the season. Carrot seed production was the largest contributor to managed hive demand, accounting for approximately 84% of estimated hive placements in the seed dataset. This suggests that vegetable seed production is already highly dependent on managed hive placement.

Together, these findings suggest two main Varroa-related risks for Tasmania's pollination-dependent industries. Some crops may be vulnerable to the loss of feral honey bees and other background pollination services, particularly apples in the Huon Valley. Other crops, particularly vegetable seed crops, may be vulnerable to reduced managed hive availability, increased hive costs and the need for strong, healthy colonies during flowering.

Further work should focus on validating these patterns through direct field observations, assessing hive quality as well as hive numbers, refining crop-specific benchmark values, and identifying crop and regional systems most vulnerable to reductions in background pollination or managed hive availability.

Acknowledgements

The authors gratefully acknowledge the growers and seed industry representatives who contributed their time and shared information about their crops and pollination practices. Their participation made this work possible and provided valuable insight into the current use of managed hives and background pollination services in Tasmanian crop production. We also acknowledge the support of the Department of Natural Resources and Environment Tasmania, whose funding enabled this project.

Ethics statement

This research was approved by the University of Tasmania Human Research Ethics Committee under Low Risk approval number H40553. All participants were provided with information about the study prior to participation, and informed consent was obtained before data collection. Grower and company data were de-identified prior to analysis, and results are reported only in aggregated form so that no individual grower, farm or business can be identified.

Funding

This project was supported by **$21,770 in funding from the Department of Natural Resources and Environment Tasmania**. The work was undertaken by the Tasmanian Institute of Agriculture, University of Tasmania. The Tasmanian Institute of Agriculture is a joint venture between the University of Tasmania and the Tasmanian Government.

References

CHAPMAN, N. C., COLIN, T., COOK, J., SILVA, C. R. B. D., GLOAG, R., HOGENDOORN, K., HOWARD, S. R., REMNANT, E. J., ROBERTS, J. M. K., TIERNEY, S. M., WILSON, R. S. & MIKHEYEV, A. S. 2023 May 24. The final frontier: ecological and evolutionary dynamics of a global parasite invasion. *Biology Letters,* 19.

HANUSCH, Y., GLOAG, R. & LATTY, T. 2025. Both Native and Introduced Non-Crop Flowering Plants Around Orchards Support Potential Crop Pollinators and Other Beneficial Insects. *Austral Entomology,* 64.

HINSON, E. M., DUNCAN, M., LIM, J., ARUNDEL, J., OLDROYD, B. P., HINSON, E. M., DUNCAN, M., LIM, J., ARUNDEL, J. & OLDROYD, B. P. 2015. The density of feral honey bee (Apis mellifera) colonies in South East Australia is greater in undisturbed than in disturbed habitats. *Apidologie 2015 46:3,* 46.

LEVESQUE, M., MCCUNE, F., FOURNIER, V. & GIOVENAZZO, P. 2025. Historical agroeconomic analysis of the relationship between commercial pollinator use and Vaccinium angustifolium (Ericales: Ericaceae) yield in Quebec, Canada (2015–2021). *Journal of Economic Entomology,* 118.

PRENDERGAST, K. S., LECLERCQ, N. & VEREECKEN, N. J. 2021. Honey bees (Hymenoptera: Apidae) outnumber native bees in Tasmanian apple orchards: Perspectives for balancing crop production and native bee conservation. *Austral Entomology,* 60**,** 422–435.

QUARRELL, S. R., WEINSTEIN, A. M., HANNAH, L., BONAVIA, N., DEL BORRELLO, O., FLEMATTI, G. R. & BOHMAN, B. 2023. Critical Pollination Chemistry: Specific Sesquiterpene Floral Volatiles in Carrot Inhibit Honey Bee Feeding. *Journal of Agricultural and Food Chemistry,* 71**,** 16079–16089.

RAMÍREZ-MEJÍA, A. F., CHACOFF, N. P., CAVIGLIASSO, P. & BLENDINGER, P. G. 2024. How much is enough? Optimizing beehive stocking densities to maximize the production of a pollinator-dependent crop. *Ecological Modelling,* 498.

SONTER, C. A., JONES, J., DAWSON, B. M., REID, J. N., SANTOS, K. C. B. S., FULLER, S., TIGHE, M., WILSON, S. C. & RADER, R. 2024. Protective covers impact honey bee colony performance and access to outside resources. *Agriculture, Ecosystems & Environment,* 368.

TASMANIA, N. R. A. E. 2024. Tasmanian Agri-Food ScoreCard.

TRAYNOR, K. S., MONDET, F., MIRANDA, J. R. D., TECHER, M., KOWALLIK, V., ODDIE, M. A. Y., CHANTAWANNAKUL, P. & MCAFEE, A. 2020. Varroa destructor: A Complex Parasite, Crippling Honey Bees Worldwide. *Trends in Parasitology,* 36.

Appendix 2. Sources used to compile fruit and berry benchmark hive-stocking rates

Note: The sources below were used to compile the published benchmark hive-stocking rates used in this report. Where a source provided values in hives per acre, values were converted to hives per hectare using 1 hive/acre = 2.47 hives/ha. Where a source provided a range, the midpoint was used in summary calculations. Benchmark values should be interpreted as indicative practical recommendations rather than exact biological thresholds, as many sources are based on extension guidance, grower experience, or crop-specific production systems. Some benchmark values may not be independent because extension guides and industry publications can repeat recommendations from earlier source material. Values in this appendix should therefore be interpreted as a practical compilation of published recommendations rather than a formal meta-analysis.

Source	Crop(s)	Benchmark information used
Berry pollination guide (Berries Australia / AHBIC)	Blueberry, raspberry, blackberry	Blueberry 6 to 10 hives/ha, with some industry advice up to 20 hives/ha; raspberry 0.5 to 2.5 hives/ha, with Australian industry advice around 8 hives/ha; blackberry literature value 2 hives/ha, with Australian industry advice around 8 to 14 hives/ha
BeeAware apples & pears	Apple	2-5 hives/ha for apples/pears
BeeAware cherries	Cherry	2 to 3 hives/ha usually used; up to 10 hives/ha recommended for effective pollination
BeeAware strawberries	Strawberry	2 to 22 hives/ha
BeeAware berries	Raspberry, blackberry and other brambles	Blackberry / bramble guidance includes suggested 2 hives/ha
NSW DPI apple pollination guide	Apple	2 to 3 hives/ha
NSW DPI cherry and plum pollination guide	Cherry	2 to 3 hives/ha generally regarded as adequate
PHA blueberry pollination fact sheet	Blueberry	1.25 to 5 hives/ha; 2 to 5 hives/ha adequate for most orchards
PHA strawberry pollination fact sheet	Strawberry	12 to 25 hives/ha
APAL apple pollination fact sheet	Apple	Average literature rate 2 to 4 hives/ha; high-density orchards may require 3 to 5 colonies/ha
OSU PNW pollination colony guide	Apple, cherry, blueberry, blackberry	PNW table gives per-acre rates including apple 0.5 hives/acre, cherry 2 hives/acre, blueberry 3 hives/acre, blackberry 2.5 hives/acre
WSU tree fruit honey bee guide	Apple	1 to 2 hives/acre adequate for most orchards
OSU controlled-environment berry pollination	Strawberry	One small hive of 6,000-8,000 bees per 1,000 m2 greenhouse strawberry
Growcom / Hort Innovation pollination practices report	Apple, Cherry, Blueberry	Surveyed hive densities; average 3 hives/ha, range 1 to 14 hives/ha for cherry, 1-6 for apple and 2-6 for blueberry
Ramirez-Mejia et al. 2024 blueberry stocking study	Blueberry	7 high-quality hives/ha or 20 conventional hives/ha for similar pollen deposition; 4 high-quality hives/ha or 20 conventional hives/ha for similar yield
MSU highbush blueberry pollination guide	Blueberry	1-5 hives per acre depending on variety
UF/IFAS southern highbush blueberry guide	Blueberry	3 to 5 hives/acre for standard-density southern highbush blueberry
New Brunswick wild blueberry pollination guidance	Blueberry	2 to 3 hives/acre under most field conditions

Appendix 3. Sources used to compile vegetable seed benchmark hive-stocking rates

Note: The sources below were used to compile published benchmark hive-stocking rates for vegetable seed crops. Where a source provided a range, the midpoint was used in summary calculations. Benchmark values should be interpreted as indicative recommendations rather than exact biological requirements, particularly because seed crop pollination needs may vary with crop type, parental line attractiveness, hybrid seed system, crop layout, bee activity and environmental conditions.

Crop	Stocking rate reported	Converted hives/ha	Source / location
Carrot	10 hives/ha	10	BeeAware vegetables page
Carrot	5-8 hives/ha	5-8	UTAS thesis on hybrid carrot seed production
Carrot	7-8 hives/ha	7-8	AgriFutures size-and-scope report
Carrot	7-8 hives/ha	7-8	Plant Health Australia carrot seed fact sheet
Carrot	6-8 hives/ha	6-8	AUSVEG / VG05064 technical report
Carrot	5+ hives/ha	5	Warren 2024 carrot seed study
Onion	30 hives/ha	30	BeeAware onions page
Onion	15-17 hives/ha	15-17	Plant Health Australia onion seed source
Onion	25-30 hives/ha	25-30	California Agriculture onion seed study
Onion	12-37 hives/ha	12-37	UTAS thesis on onion seed production
Brassica	3-6 hives/ha	3-6	BeeAware / canola-brassica guidance
Brassica	3-6 hives/ha	3-6	Plant Health Australia canola/brassica fact sheet
Brassica	3-5 hives/ha	3-5	AgriFutures size-and-scope report, cauliflower seed