Varroa destructor: IPM for tropical Australian beekeepers

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Executive Summary

Wednesday 22nd June 2022 will be remembered by beekeepers around Australia. *Varroa destructor*, the most destructive pest of European honeybees around the world, was found in New South Wales. The Australian beekeeping industry is now undergoing transformational change on what it means to be a beekeeper and how to go about keeping bees. This report is aimed at tropical climate recreational and small commercial beekeepers experienced in beekeeping but with minimal to no experience in Integrated Pest Management (IPM) or management of Varroa mite. It will also be of interest to beekeepers on a larger scale, in temperate climates, or with previous experience seeking more knowledge of biotechnical mite management methods.

Part one introduces IPM and appropriate goal setting. Key stakeholders who need to be considered in a successful Varroa management plan are introduced. The Australian honey and pollination industries cover a wide range of beekeeping goals and methods. Biology of *Apis mellifera*, *Varroa destructor,* viruses and other pathogens vectored by Varroa must be considered. Potential impacts of other pests both endemic in Australia (such as Small Hive Beetle) and threatening our borders (such as Tropi mite) need to be included in an effective long term management plan.

Part two guides beekeepers through a Varroa mite Integrated Pest Management framework to successfully unite these stakeholders. The IPM Broodcomb is based on the IPM triangle commonly used for pest management in other agricultural industries. It has five steps designed for beekeepers who may be unfamiliar with IPM concepts and strategies. The plan includes Varroa resistant queens, hive husbandry, mite threshold monitoring, breaking the mite reproductive cycle (with a focus on chemical free biotechnical methods) and removing phoretic mites. Each section includes current research, case studies and practical applications.

Part three describes the difference between Varroa management over the short, medium and long term future. The initial invasion period will see a die off in the huge number of feral hives in Australia. This period could take years and will see massive fluctuations in mite reinvasion numbers over short periods of time. The Varroa management plan during this phase may be very different from the long term plan that a beekeeper would be willing to pass on to the next generation of beekeepers.

Recommended actions which could assist the Australian Beekeeping industry manage *Varroa destructor* include increased funding for mite resistant queen breeding programs, improved mite monitoring methods, education for beekeepers on biotechnical methods, and marketing training for beekeepers facing increased management costs and potential lower consumer confidence.

World class biosecurity practices which excluded Varroa for so many decades are now reaping benefits for Australia. Beekeeping industries around the world successfully operate while managing Varroa. This provides Australian beekeepers with extensive research and practical learnings from a range of climates. The ability of the Australian beekeeping industry to adapt and thrive in the world's most variable farming climate shows that Australian beekeepers are up to the task.

Keywords: beekeeping, Integrated Pest Management (IPM), Varroa, biotechnical, tropical

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***Varroa destructor*: IPM for tropical Australian beekeepers**

Foreword

My husband Luke Edwards and I own and run Honeyvale Farm, the home of our beekeeping business Ballina Honey. We have an integrated farming enterprise with bees, pigs, cattle and pecans in the beautiful subtropical Northern Rivers of New South Wales, Australia. The way we farm reflects our passion for our environment and our community. Ballina Honey is small commercial with only 70 hives and buys bulk honey and beeswax from local beekeepers. As a small business we are very conscious of both protecting local livestock through strong biosecurity practices and protecting our customers' confidence with high quality pure honey and beeswax.

In 2022 I came across Nuffield Australia while studying at Southern Cross University. This looked like a good way to learn more about the risk from little known Tropilaelaps mite north of Australia. Meanwhile, unbeknownst to Australian beekeepers, *Varroa destructor* was steadily building numbers in hives 700km to the south of us in Newcastle. Varroa mite was discovered and declared on 22nd June 2022, a moment which will never be forgotten by the Australian beekeeping community. Before the next round of Nuffield interviews I changed my study topic to Varroa mite and packed my bags to volunteer on the eradication effort in Newcastle. Before I returned from the last of my Scholarship travels the DPI declared the end of the eradication effort and the start of 'Transition to Management'. It appeared it was going to be almost impossible for a subtropical honey business to keep supers on year round and make beeswax products with a chemical free guarantee that customers could be confident in.

The table below (Table 1) lists key aspects of my travels. Each location had a unique beekeeping story that helped build a picture of what beekeepers might expect or create in Australia. I made sure to visit researchers, commercial operators of all sizes, sideline businesses and recreational beekeepers both conventional and alternative in as many places as possible to reflect the range of beekeepers in Australia.

Varroa destructor arrived in the lush subtropical forests of Hawai'i in 2007. Small Hive Beetle soon followed in 2010. Seeing such a similar beekeeping culture and climate recover from this devastation to continue as a thriving industry was a strong boost to my confidence. UK beekeepers chemically treated mites when they first arrived in 1992, but like Hawai'i started seeking other options. Seeing first hand how Steve Riley at Westerham Beekeepers has undertaken the journey towards mite resistant bee stock in a club level project accessible for any beekeeper was a major highlight. Since the arrival of Varroa mite in Germany 50 years ago, many beekeepers have gone through the chemical treatment treadmill still found in the USA and emerged out the other side with the help of extensive research. A wonderful highlight of my travels was having a range of biotechnical, chemical free management methods demonstrated by Thomas Van Pelt on his 100 hives, all managed chemical free despite not yet having Varroa resistant stock. This was the golden ray of hope that I had been looking for.

To truly understand how best to manage *Varroa destructor* in Australia will be a lifetime endeavour. Beekeeping will never be the same again, but my goal is to work with the beekeeping community to develop methods suitable for our climate and culture. It resonated with me that both Steve Riley and Thomas Van Pelt spoke about beekeeping still being about bees, not about mites. Nuffield has provided the launching pad to make this happen closer to home. Neither Nuffield nor Agrifutures Australia influenced who I visited or where I travelled. This is a special and appreciated feature of this Scholarship. I feel this makes my journey very impartial and completely driven by goals that can be trusted by beekeepers for beekeepers.

Table 1. Travel itinerary

Travel date	Location	Visits/contacts
19-25th February 2023	Oahu, Hawai'i, United States of America Big Island, Hawai'i, USA	Dr Ethel Villalobos, University of Hawai'i Katie Metzger, Hanai Hives Dennis Takata, Hawai'i Tropical Honey Carey Yost, Jim & Carey's Happy Bees Kelly O'Day, Kona Queen Whendi Grad & Garnett Puett, Big Island Bees Zak Heintzelman, Heintzelman Apiaries Ron & Peggy Hanson, The Honey Bee Company Jen Rasmussen, Paradise Nectar Apiaries
26-7th February-March 2023	Gainsville, Florida USA Georgia, USA California, USA	Dr Cameron Jack, University of Florida Chris Leach, The American Honeybee Co. Allen & Mindy Merritt, beekeepers Steve Starks & John Dulaney, Save the Bees Rescue Ray Latner, Dadant & Sons Matthew Thomas, Natural Bridge Honey Farm Stephen Cutts, Apiary Inspector Florida Department of Agriculture Dr Jennifer Berry & Dr Lewis Bartlett, University of Georgia Bob Binnie, Blue Ridge Honey Co. Randy Oliver, Golden West Bees Bonnie Morse, Bonnie Bee & Company
2-7th April 2023	North Island New Zealand	Frank Lindsay ONZM, Beeline Supplies Ltd. Dr James Sainsbury, Plant & Food NZ Peter Grifford, Head Trainer, K9 Search Medical Detection Dave Campbell, CEO, Manuka Health NZ Brian McCall, National Hive Manager, Manuka Health Barry Foster, Tawari Apiaries Ltd John Mackay, Technical Director, Dnature Shaun Wakeford, Beequip NZ Mark Berry, Arataki Honey Martin Crisp, East Valley Honey
17-19th May 2023	Sydney NSW Australia	Dr Mary Whitehouse, Macquarie University Dr Fazila Yousuf, Macquarie University 2023 NSW Apiarists' Association Conference
22-26th May 2023	Nadi, Fiji	Pacific Islands Bee Congress
15-16th June2023	Toowoomba, Queensland, Australia	2023 Queensland Beekeeper's Conference
29-5th	England	Julie Parker, London Bee Inspector

May-June 2024	UK Scotland Wales England	Josh Frazer, Lake District Honey Company Dr Stephen Martin, University of Salford Shan & Clive Hudson, Bryn Fedw, Gwynedd Steve Riley, Westerham Beekeepers, Surrey
6-13th June 2024	Germany	Thomas Van Pelt, Bergbienen & Varroaresistenz Ivan Curic, Meisterhonig Torben Schiffer, Hamburg
14-17th June 2024	Sweden	Dr Barbara Locke Grander, Swedish University of Agricultural Sciences, Uppsala Karina Tomtlund, regional bee health advisor Preben Kristiansen, Apinordica
18-19th June 2024	Germany	Dr Ralph Büchler, Bee Institute Kirchhain

Figure 1. The author visiting the Swedish University of Agricultural Sciences apiaries at Uppsala. (Source: Author).

Acknowledgments

This amazing Nuffield journey could not have happened without the support of some sensational people who I can't thank enough. Firstly Southern Cross University for throwing Nuffield in my path. Dr Hanabeth Luke, Dr Cooper Shouten and Jess Martin at Honey on Carlton confirmed for Nuffield that I was worth it. Nuffield Australia decided that I was worthy of a scholarship. The awesome AgriFutures Australia have kindly funded my scholarship and put an incredible amount of funding into beekeeping in Australia. Abbey O'Callaghan and Sheridan Ingold at AgriFutures Australia have never complained that major family issues along the way stymied my efforts to keep everyone updated at the time of my travels.

The overwhelming number of researchers and beekeepers around the world who have freely given their time, their knowledge and their hospitality has been truly humbling. Jim and Carey Yost in Hawai'i, Shaun Wakeford in New Zealand, Dr Stephen Martin in Scotland, Steve Riley in England, Thomas Van Pelt in Germany, Torben Schiffer in Germany and Susanne Stenlund and David Morrison in Sweden kindly opened their homes to accommodate me on my travels. Honeyvale Farm and Ballina Honey have been privileged to have a team of dedicated, innovative people to keep the ball rolling on farm even when time differences made it hard to get in touch with me. Last but never least, my wonderful husband Luke Edwards who I have taken to the ends of the earth and back in the pursuit of good beekeeping practices.

Abbreviations

AFB	American Foul Brood
AHBIC	Australian Honey Bee Industry Council
AI	Artificial Insemination
APVMA	Australian Pesticides and Veterinary Medicines Authority
AQBBA	Australian Queen Bee Breeders' Association
˚C	Degrees Celsius
cm	centimetre
DPI	Department of Primary Industries
DWV	Deformed Wing Virus
EFB	European Foul Brood
EU	European Union
IPM	Integrated Pest Management
kg	kilogram
km	kilometre
MAQS	Mite Away Quick Strips
MNR	Mite non-reproduction
MRL	Maximum Residue Level
NSW	New South Wales
NZ	New Zealand
OA	Oxalic acid
PMS	Parasitic mite syndrome
PNG	Papua New Guinea
SHB	Small Hive Beetle
SMR	Suppressed mite reproduction
Tropi	*tropilaelaps* mite, *tropilaelaps mercedesae* or *clareae*
UBeeO	Unhealthy Brood Odor
USA or US	United States of America
USDA	United States Department of Agriculture
Varroa	varroa mite, *varroa destructor*
VSH	Varroa Sensitive Hygiene
VPS	Varroa parasitisation specific compounds
WSP	William Samuel Pender (a frame size)

Objectives

Objective 1: Introduce Integrated Pest Management goals and stakeholders

Part I introduces Integrated Pest Management and encourages beekeepers to set clear goals. Australian beekeeping culture, *Apis mellifera* biology, *Varroa destructor* biology and other pathogen risks must then be considered to plan successful Integrated Pest Management. This objective is designed to combat common misinformation and misunderstandings in this area, as well as provide a holistic view.

Objective 2: Provide an Integrated Pest Management framework to assist Australian beekeepers in making Varroa management decisions

Part II walks beekeepers through the Integrated Pest Management Broodcomb. This covers breeding for mite resistance, hive husbandry, mite threshold monitoring, interrupting the mite reproductive cycle and removing phoretic mites. The focus is on biotechnical methods suitable for tropical areas with supers on and brood present year round. Chemical and other controls are also covered.

Objective 3: Encourage Australian beekeepers to make informed Varroa management decisions over the short, medium and long term

Part III considers the three aspects of the future for the Australian beekeeper. First, the invasion stage when Varroa initially arrives in an area. Second, using the IPM Broodcomb to plan year on year. Third, making decisions now which will reflect what beekeepers want our industry to be for the next generation of beekeepers.

Introduction

Integrated Pest Management of *Varroa destructor*

Varroa destructor is the most destructive pest of European honeybees globally (Ziegelmann et al., 2018). On every beekeeping continent beekeepers have had to change their industry, their methods and their way of thinking to survive once Varroa mite arrived. After the largest multi-agency plant biosecurity response in Australia's history, Transition to Management took over from eradication in New South Wales (NSW) on 19 September 2023 (NSW Department of Primary Industries (DPI), 2023). Varroa management is an area of constant change and progress in both research and field practice. That research paper being quoted may have been disproven or shown to be only true under those conditions and in that location, almost as quickly as that popular YouTube video. This makes for an exciting field of future opportunities. All assumptions should be treated with caution.

Integrated Pest Management (IPM) is the best practice process of combining a range of management methods to keep pest numbers consistently below a level which would harm the goals of the beekeeper and the bees (NSW DPI (2), 2023). This begins with setting goals which consider ethical, environmental and economic aspects. Beekeepers may be aiming to save the bees, to have honey and pollination for the garden or to provide an income to support their family. This is a living plan, with goals set and targets regularly reviewed. This is necessary as the invasion phase will be different to subsequent years of more stable mite numbers. The impacts and goals of all stakeholders from the industry to the pest must be considered for the plan to be effective. This should include the exact point at which the outcome exceeds the ethical or economic cost to the beekeeper. It is assumed that beekeepers know and follow their own State legislative requirements, while remaining curious about other methods. No prior knowledge of IPM has been assumed. Standard IPM teachings have been adapted to suit beekeepers.

Part I: Defining key stakeholders

Australian beekeeping industry snapshot

The farmgate value of the Australian beekeeping industry in 2023 was $363.6 million annually, with more growth forecast in pollination services by Australia's 1,872 commercial beekeepers and 630,000 hives. This does not include the 47,111 recreational beekeepers who create a sector valued at $260.2 million with 235,555 hives. This data from Clarke and Le Feuvre (2024) includes the start of the Varroa incursion response. These groups are eclipsed by the $12.9 billion dollars of Australian crops at least partially reliant on pollination by bees (Gillespie, Clarke and Frost, 2024).

Varroa mite is likely to cause the industry a 50-60% loss of beekeepers (mostly recreational beekeepers), a 16-90% die off in feral hives creating greater demand for pollination services and less competition for honey, a 30% increase in management costs, and a small reduction of 2-5% in the number of commercial hives after several years of adjustment. The initial years could see commercial hive losses of anywhere between 16% (as in New Zealand) and 75% or more as seen in California (AgriFutures (3), 2024).

When Varroa swept through the US industry in 1987 it caused the "biggest catastrophe to befall apiculture since its establishment in this country in the 1600s" (Doebler, 2000). 35 years later US beekeepers have a steadily climbing average of 40% hive deaths every year, with Varroa as the primary cause. This is in stark contrast to New Zealand, where annual hive losses rose every year since surveys started in 2015 to 13.5% in 2021 but have now fallen to 10.76% (Ministry for Primary Industries, 2025). Stringent biosecurity controls have allowed Australia to become the last large scale beekeeping industry to have Varroa. This allows Australian beekeepers to benefit from half a century of dedicated research and practical trials around the world.

Australian beekeepers

Australia covers as much variation in beekeepers as it does climate and floral resources (Table 2). Varroa management methods and education programs designed to change the way beekeeping is done need to cater to this variation to be effective. Of the 50-60% of beekeepers likely to leave the industry in the face of Varroa, 90% will be recreational beekeepers (AgriFutures (3), 2024). Many sideline business and small commercial beekeepers are determined to survive Varroa but rely on the naturally chemical residue free status of specialty hive products. These beekeepers are using honey, beeswax, pollen, propolis and royal jelly in direct sales of food grade items like cosmetics.

Table 2. Variations in beekeeping styles and climate across Australia must be considered as these will impact which Varroa control methods are suitable.

Tropical climate beekeeping	Temperate climate beekeeping
• Supers on all year round • Brood all year • Swarms any time of year • Drone brood seasonal to all year • Honey flows and brood revolve around the unpredictable arrival of the wet and dry seasons • Bees do not live as long due to flying all year • Greater Small Hive Beetle pressure	• Supers off in winter • Brood laid in March for winter brood break (longer lived bees) • Laying resumes end of winter ready for spring swarming • Drones seasonal only • Honey flows and brood revolve around predictable summer/ winter • Swarm season gradually getting earlier year on year
Recreational beekeepers	**Commercial beekeepers**
• Wide array of non-standard hive shapes and designs; top bar, Warre, Flow Hive, long langstroth • Ranging constant inspections to never • Ranging lots of money spent to spare parts only used • Generally stationary hives • May struggle to find accurate, trustworthy education sources	• Low average wage $70,000pa • Langstroth hives • Regular hive inspections • Almond pollination sees 200,000 hives from Eastern Australia gather • Australia's most migratory livestock, may move between temperate and tropical areas • Average 300-350 hives (Clarke and Le Feuvre, 2024)

Apis mellifera in Australia

The European honeybee was first successfully imported to Australia in 1822 when seven hives arrived in Sydney with convicts aboard the *Isabella*. These were the black English *apis mellifera mellifera* still found in some areas. Most early imports soon absconded for the bush. Later that century came *apis mellifera ligustica.* These Italian bees were kinder on beekeepers and brought in greater honey flows. Large volumes of nectar and pollen were required to raise lots of bees and care for such a large brood nest, but the Australian bush was up to the task. Cordovan and Carniolan bees, running smaller brood nests more appropriate for colder climates, were also brought to Australia (Australian Food Timeline, n.d.).

Australia is now the last place where feral hives exist in high densities, with up to 150 hives per square kilometre (Gosden, 2023). The value of pollination provided by this cohort is impossible to fully determine until it is no longer there. Figure 2 below is basic bee and mite biology regardless of continent or climate. This is a vital reference to revisit when planning biotechnical methods. Not pictured is the lifecycle of the queen, who emerges from her queen cell on day 16. She will be mated and laying by approximately day 27. Up to 12% of hives may have a second queen (Wildflower Meadows, 2022).

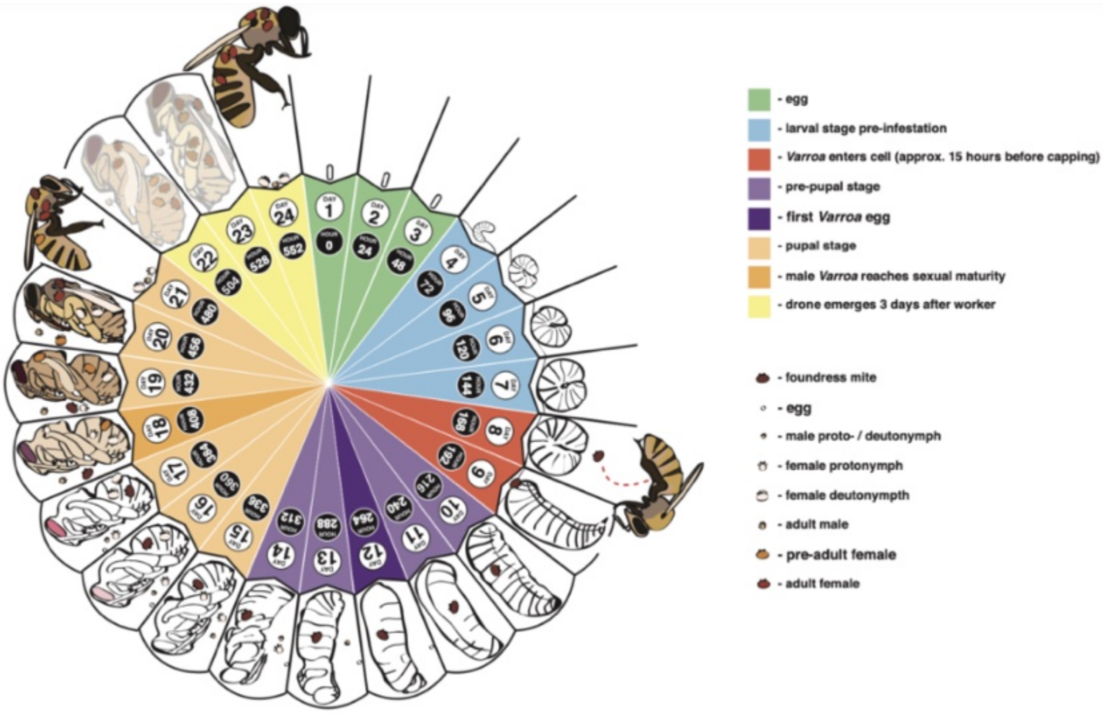

Figure 2. Reproductive cycle of Varroa mite and bees. A mated female mite enters the worker or drone brood cell about 15 hours before the cell is capped. Several days later the mite lays a male egg, then a female egg every 30 hours. Any mites still immature when the worker bee emerges on day 21 (day 24 for drones) will not survive (Source: Evans and Cook, 2018).

Varroa destructor and friends

Varroa jacobsoni and *Apis cerana* (the Asian honeybee) have a longstanding relationship allowing *jacobsoni* to sustainably parasitise *cerana* in Asia. Asian honeybee has a range of defences against this mite (Grindrod and Martin, 2022) which are beyond the scope of this report. When humans brought *Apis mellifera* into Asia, it encountered this pair on a regular basis. Sometime before 1957 an enterprising mite jumped onto a European honeybee and realised this was the perfect host… zero defences but a convenient human determined to keep the hive alive or park it close to another host to jump onto! The density of European hives results in varroa being one of few parasites that can kill the host and still spread unhindered. Humans have spread what has now become a genetically different species, *Varroa destructor*, throughout Asia and to every other beekeeping continent.

Varroa mite is equivalent to a scrub tick the size of a saucer sucking on the immune system of a human and stopping them from acting and thinking clearly.

There are important points to note around the Varroa part of the lifecycle in Figure 2:

- A mite emerges from the cell already mated. It only takes one mite to enter a hive. This mite could have been picked up by a bee sharing a flower or in a mass of mites from the hive robbing out another dying hive.
- There is no more eradication of mites. They are now a colony within the hive just like the drones or the workers. It is not possible or reasonable to keep numbers at zero in an infested area near other hives (including ferals).
- Mites can survive 27 days to 5 months in the hive, 7 days outside the hive but only 48 hours in a freezer. Mites can be transferred on bee suits and equipment. Freezing is a good biosecurity measure for equipment and frames.
- The mite has a “phoretic” stage where it attaches to and feeds on adult bees for 5-11 days followed by a reproductive stage where it feeds off pupae in capped brood (Figure 2). Male mites are only present in brood. Female mites require both stages to live.
- Female mites take longer than the queen bee to start breeding again after a hive wide brood break.
- On average 3 mated daughters emerge from worker brood and 5 mated daughters from drone brood. Varroa has exponential reproduction!
- An in depth description of *Varroa destructor* biology is beyond the scope of this report, but links to more information can be found in Appendix 1.

Tropi mite

North of Australia in Papua New Guinea (PNG) *Varroa jacobsonii* has once again jumped onto *Apis mellifera*. Here it shares *Apis mellifera* brood cells with another mite, *tropilaelaps mercedesae* and *t. clareae*. This new pest jumped onto *Apis mellifera* from *Apis dorsata,* the giant honeybee of southern Asia.

Important points on Tropi mite for Australian beekeepers (adapted from Veto-pharma, 2024):

- Tropi mite has a similar lifecycle to *Varroa destructor* but only feeds on bee larvae and pupae, no adult feeding stage like Varroa so no phoretic stage

- Faster and more efficient reproduction, with eggs laid every 24 hours and 70% of female mites reproducing, compared to 30 hours and 50% of female mites reproducing in Varroa mite
- Very difficult to spot as they are smaller, more transparent and quicker. Uncap brood or look at mite fall on base boards (Figure 3A and 3B) rather than using an alcohol wash or sugar shake. You can also use brood depilation, removing cell caps with a wax strip (link in Appendix 1).
- Best managed by learning how to identify and monitor for tropi, then use brood breaks and trap frames to significantly reduce populations. Other treatments which penetrate brood cappings may be effective, such as formic acid.
- Only 4km (kilometres) separate Australia and Papua New Guinea at their closest point, so tropi mite is a very high biosecurity risk
- An in depth look at the various Tropi mite species is beyond the scope of this report, but links to more information can be found in Appendix 1

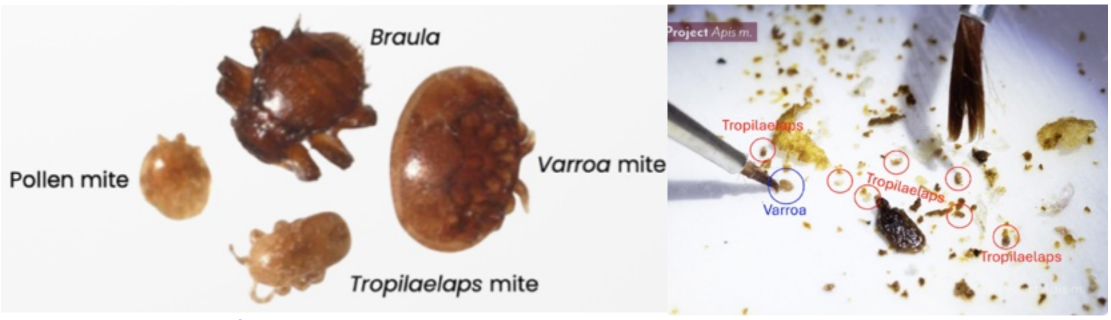

Figure 3. A. Pests of the European honeybee. Pollen mites do not need to be reported. Report endemic braula fly and Varroa mite to the NSW DPI on 1800 900 090 or to your own state authority. Tropi mite is exotic to Australia. Report tropi to the Exotic Plant Health Hotline on 1800 084 881. B. Identifying varroa and tropi mites on a base board can be difficult (Source: Véto-pharma, 2024).

Small Hive Beetle

In both the USA and PNG *Varroa destructor* has important interactions with another pest, *aethina tumida (*Figure 4A and 4B). Small Hive Beetle (SHB) is a hive scavenging native of sub-Saharan Africa. Australian beekeepers in warmer areas of the East coast will be very familiar with this pest. After two decades of SHB (having arrived in Australia in 2002), most Australian bees are adapted and resistant enough to manage SHB alone or with minimal husbandry help. Queen bloodlines incapable of this would have disappeared from feral hives in infested areas. Some important points on SHB:

- Unlike Varroa mite, SHB can live and travel with no reliance on European honeybees. Larvae leave the hive and crawl up to 200m away to pupate in soil. Biological controls such as Dalotia rove beetle are being trialled.
- Adult beetle can smell and find hives 16km away to mate and lay eggs in. A simple trap can be made by leaving a solar wax melter open of an evening when SHB are flying. Close it after dark and leave it closed in full sun the next day.
- A hive weakened by Varroa will be vulnerable to overwhelm by SHB. This will be very apparent in the initial mite invasion phase with large numbers of feral hives creating the perfect breeding ground for swarms of SHB.
- More information on SHB can be found on the NSW DPI Prime Fact 764: Small hive beetle management options (link in Appendix 1).

Figure 4. A. Small Hive Beetle larvae (smaller, on left, 'crinkle cut chip' look) and wax moth larvae (larger, on right, smoother look), both scavenger pests best managed by keeping a strong hive with no more space than bees can control. B. Adult small hive beetles are commonly seen when the hive lid is first opened. (Source: Author)

Viruses and other pathogens

Australia has a small number of dangerous bee pathogens which beekeepers should know how to identify (Table 3). Most bee viruses currently found in Australia have no clinical symptoms. This is very different to other parts of the world, where virus damage causes greater damage to bee health than Varroa mite. Viruses and other pathogens may only show symptoms when bees come under stresses such as being moved, cold weather or poor nutrition. The fat body of the bee which *Varroa destructor* feeds on is the immune system and energy store of the bee. Damage to this system means that viruses previously held in check begin to show symptoms. Parasitic mite syndrome (PMS) is a disease complex highly correlated with excessive levels of Varroa mite (Bee Aware, n.d.). PMS looks similar to European Foul Brood (EFB) which Australian beekeepers should be familiar with monitoring for. If not please download the free Biosecurity Manual for Beekeepers (2016) in Appendix 1.

Deformed Wing Virus (DWV) is the most prevalent damaging bee virus worldwide. DWV-A is being overtaken by a more virulent strain, DWV-B. Extensive testing has not yet found DWV in Australia but beekeepers should remain vigilant and ring the Exotic Plant Disease Hotline on 1800 084 881 if they see a suspected case in their hive (Figure 5). This virus could be in Australia already but with no clinical symptoms until Varroa becomes a vector. Australian beekeepers cannot readily import mite resistant queens or drone semen from overseas primarily due to the risk of DWV. This very prevalent virus can be transmitted from drone sperm to the next generation, though the CSIRO has a 2024/25 project running to delineate this risk (AgriFutures (1), 2024). The only defence against viruses is to keep Varroa numbers low, maintain healthy bees and supply varied pollen sources.

Table 3. Pathogens of *Apis mellifera* in Australia and viruses commonly affecting *A. mellifera* overseas. Note endemic means here in Australia and exotic means not seen in Australia or under eradication. Viruses are cutting edge research being constantly updated with new discoveries.

***Apis mellifera* pathogen type**	**Pathogen name**
Fungal, endemic and notifiable	Chalkbrood *(Ascosphaera apis)* Nosema *(Nosema apis or cerana)*
Bacterial, endemic and notifiable *Quick test: look for sunken brood cappings and unhealthy brood. A piece of grass inserted into a capping will rope out (like a string) if AFB.*	American foulbrood *(Paenibacillus larvae)* European foulbrood *(Melissococcus plutonius)*
A small sample of common endemic viruses which may not always show symptoms	Black Queen Cell virus Kashmir bee virus Sacbrood (SBV, Iflavirus genus) Bundaberg bee virus 6 (Similar to DWV) Darwin bee virus 3 (Similar to DWV)
Endemic viruses recently detected in Australia with Varroa (Schouten and Remnant, 2024)	Apis Rhabdovirus-1 (ARV-1) Apis Rhabdovirus-2 (ARV-2)
Some highly damaging exotic viruses associated with Varroa	Slow Bee Paralysis virus (SBPV) Acute Bee Paralysis virus (ABPV)
A virus of Varroa (Damayo et al., 2023)	Varroa destructor virus 9 (VDV-9)
Highly damaging exotic viruses known to replicate within Varroa*	Deformed wing virus A (DWV-A) Deformed wing virus B (DWV-B) Lake Sinai 2
Disease complex associated with Varroa	Parasitic Mite Syndrome (PMS)

*DWV has been found in an incursion of *Apis florea* (red dwarf honey bee) found in north west WA on the Burrup Peninsula. This bee has it’s own mite species, Euvarroa. The incursion is in a remote, isolated area and is under eradication (Remnant, 2025).

Figure 5. Classic crumpled wing presentation of Deformed Wing Virus in Karina Tomtlund’s apiary, Sweden. Not all infected bees will show symptoms and not all crumpled wings will be DWV. Deformed wings can also be the result of mite predation of pupae, temperature swings, poor nutrition, pesticide exposure and genetic mutations (Source: Schouten and Remnant, 2024).

Part II: Successfully uniting stakeholders with the IPM Broodcomb

Beekeepers may not be familiar with the standard Integrated Pest Management triangle used to guide decisions in industries such as cotton and macadamias. The Integrated Pest Management Broodcomb (Figure 6) has been developed to provide a plan more specific and appropriate to beekeepers. This is designed to guide Australian beekeepers unfamiliar with the IPM process through making a personalised Varroa management plan suited to their goals, their beekeeping and their bees. This journey begins with the desired end in mind and is reviewed regularly.

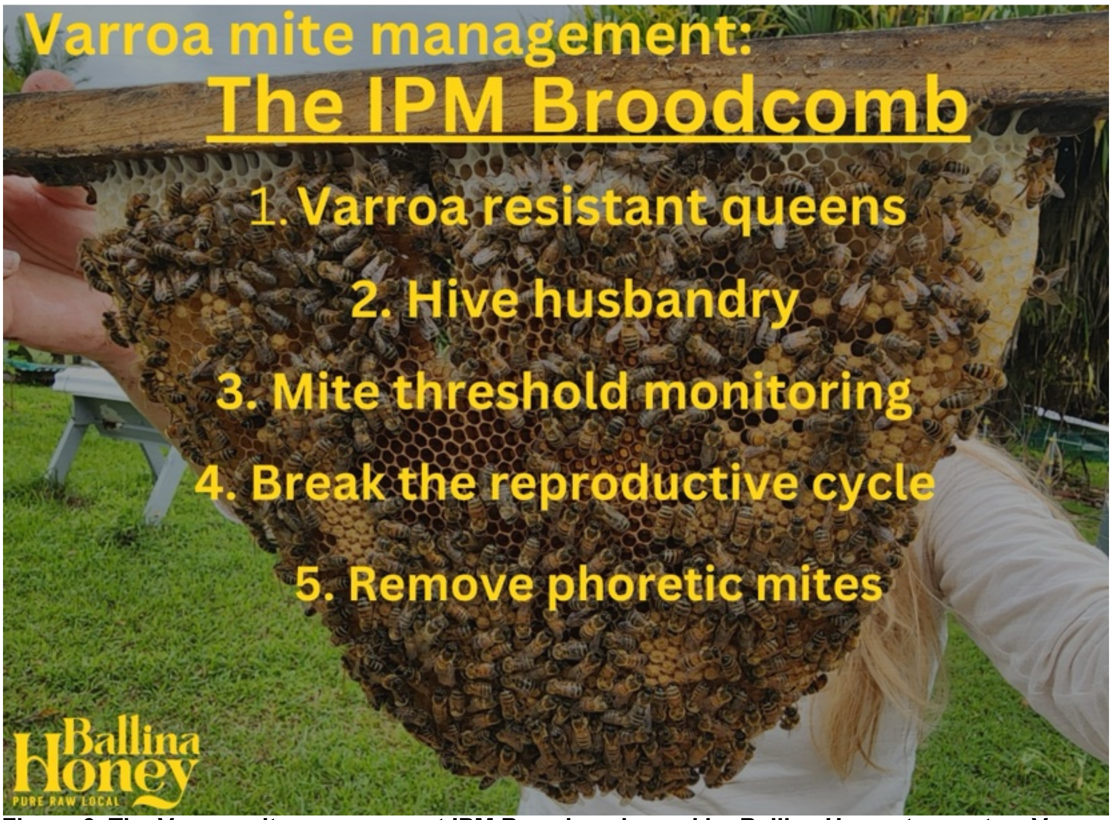

Figure 6. The Varroa mite management IPM Broodcomb used by Ballina Honey to create a Varroa management plan. Review the plan regularly. Comb from a top bar hive at Jen Rasmussen's Paradise Nectar Apiaries, Hilo, Hawai'i. (Source: Ballina Honey)

IPM already utilised by beekeepers: Small Hive Beetle

Beekeepers in warmer areas of the Australian East coast will already be familiar with their IPM plan to manage Small Hive Beetle, even if they did not think of it as an IPM plan. Recognising the same pest management patterns may help in making a Varroa plan. Sally's decision making steps are numbered to match the IPM Broodcomb.

Queensland beekeeper Sally heads to her apiary of 20 hives on her neighbour's farm to do an inspection. After a wet summer she is not surprised to see Small Hive Beetle in every hive.

1. **Resistant queens**
   Sally generally uses her own locally adapted queens. When Sally buys queens in she makes sure they are from a similar management system and climate area with queens that are successful under SHB pressure.
2. **Hive husbandry**
   Sally's hives have good morning sun. She uses vented base boards with oil traps underneath. The ground below the hives has sheets of tin to keep larvae from pupating in the soil directly under the hive. The grass is kept short in the apiary to dry the soil out quickly after rain. Sally makes sure not to add an extra box until the bees need it and if a hive is struggling she may requeen and reduce the hive down so bees can still defend the space. There are no tight crevices or frames pressed up against the side wall so SHB cannot lay eggs where bees cannot patrol and protect the space.
3. **Threshold monitoring**
   Sally judges the number of hive beetle in each hive compared to what she usually sees this time of year. She considers the recent weather and the size of each hive. Some of her hives exceed the SHB threshold that Sally is confident they can deal with.
4. **Break the reproductive cycle**
   One hive has unfortunately succumbed to a SHB slime out. It has the shiny look of honey fermenting and has many hive beetle larvae in the brood box. This hive has the surviving queen and bees moved to a nucleus box with donor brood of all ages from a stronger hive. The slimed out frames are removed and disposed of immediately to disrupt the SHB reproductive cycle.
5. **Remove adult pests**
   Sally squashes beetles found under lids and adds two reuseable V traps with apple cider vinegar and vegetable oil to the top super of each hive. She could add a folded Chux cloth or square of Lino with the rough side up on top of the frames to catch adult beetles, though these have the risk of adding microplastics to honey. She could add a fipronil cassette bait trap to the more vulnerable nucleus hive, though these traps have the risk of small amounts of fipronil leaching through the plastic casing.

1. Varroa resistant queens

The first step in managing any pest is to preference stock resistant to damage from that pest. Varroa resistant traits of both feral and kept *Apis mellifera* are another Nuffield report in themselves, a research career and profession for many beekeepers around the world. This is a brief overview of what is currently known.

Selecting the right species

Varroa destructor is specific to the European honeybee. This is not a native species conservation effort! If the goal is to save the bees, no Varroa management is required. Australia has over 2,000 native bee species. These primarily solitary and often spectacular looking bees are in dire need of habitat assistance. From Sydney north on the East coast people can even enjoy Australian native stingless *Tetragonula* and *Austroplebeia* sugarbag bees in a hive with a small honey harvest. All native bees have a very different brood cycle not compatible with Varroa mite. Australian native bees have a fast growing industry for pollination, honey and hive sales which will continue growing as Varroa affects more *Apis mellifera* beekeepers. For more information contact the Australian Native Bee Association (link in Appendix 1).

Varroa destructor has highlighted our overreliance on one species for Australian pollination (Wheen Bee Foundation, n.d.). However, *Apis mellifera* remain unmatched in Australia for their ability to fly in large numbers at low temperatures as required for almond pollination.

Traits of mite resistant *Apis mellifera*

Research on the mechanisms behind Varroa resistant *Apis mellifera* populations around the world is continuously evolving. Mite resistant traits are hotly debated. This covers actions undertaken by adult bees, brood, mites, and the colony as a whole (Figure 7). The frequency of worker bees uncapping and recapping brood cells to disrupt mite breeding is recognised world wide as a marker for Varroa resistant bees. This was unfortunately confirmed by how uncommon this trait is in Australian bees (Figure 8)! Varroa Sensitive Hygiene (VSH) and Supressed Mite Reproduction (SMR) are important components of a colony level strategy known as Mite Non-Reproduction (MNR). VSH nurse bees actively seek Varroa infested cells to uncap then pull the pupa out to interrupt mite breeding. SMR brood can supress the ability of mites to reproduce under cell cappings without assistance from adult bees. MNR can collectively keep mite numbers below the threshold for damage to the colony (AgriFutures (2), 2024).

Mite resistant bees actively reduce mite reproduction.
Mite numbers stay below levels that would damage the hive.

Mite tolerant bees are not as badly affected by mites as susceptible bees.
Mite numbers stay at levels that damage the hive.

Bees may also be resistant to or tolerant of high virus levels in the hive

(Mondet, 2025).

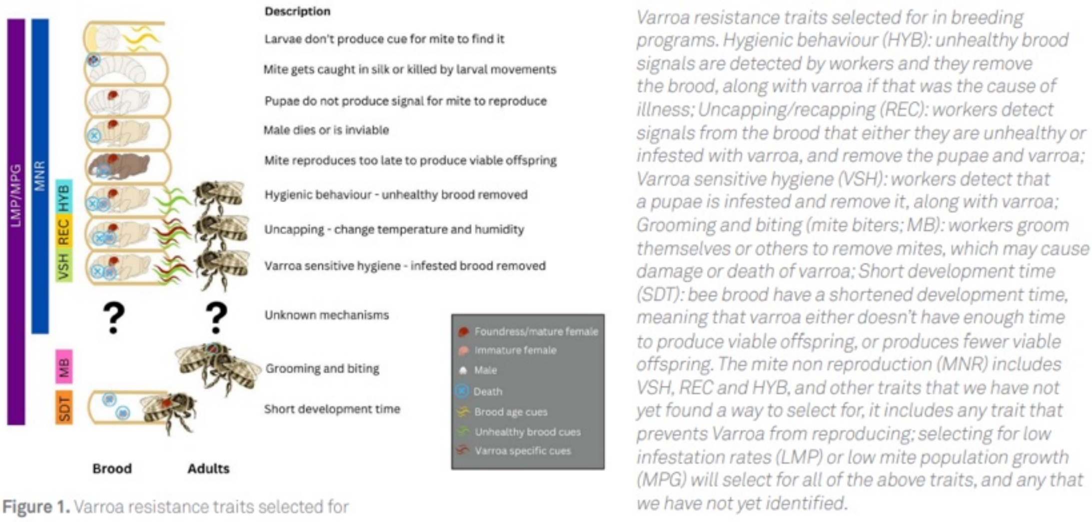

Figure 7. There are a wide range of Varroa resistant traits selected for in breeding programs, as well as unknown contributing traits (Source: AgriFutures(2), 2024).

The exact genetic markers for resistance are not yet clear, but these are genetic traits passed on through the queen rather than learned from other workers (Martin et al., 2024). These traits are likely to be recessive, meaning that they will always be passed on by a Varroa resistant queen but will only be visibly expressed if the drone also passes on that trait (Oliver, pers.comm., 2023). This means that if a mite resistant queen mates with twelve drones and only six pass on mite resistant genes, all her daughters will carry the mite resistant trait but only half of the hive is going to show this behaviour. It is currently unknown how many separate genes contribute to mite resistance.

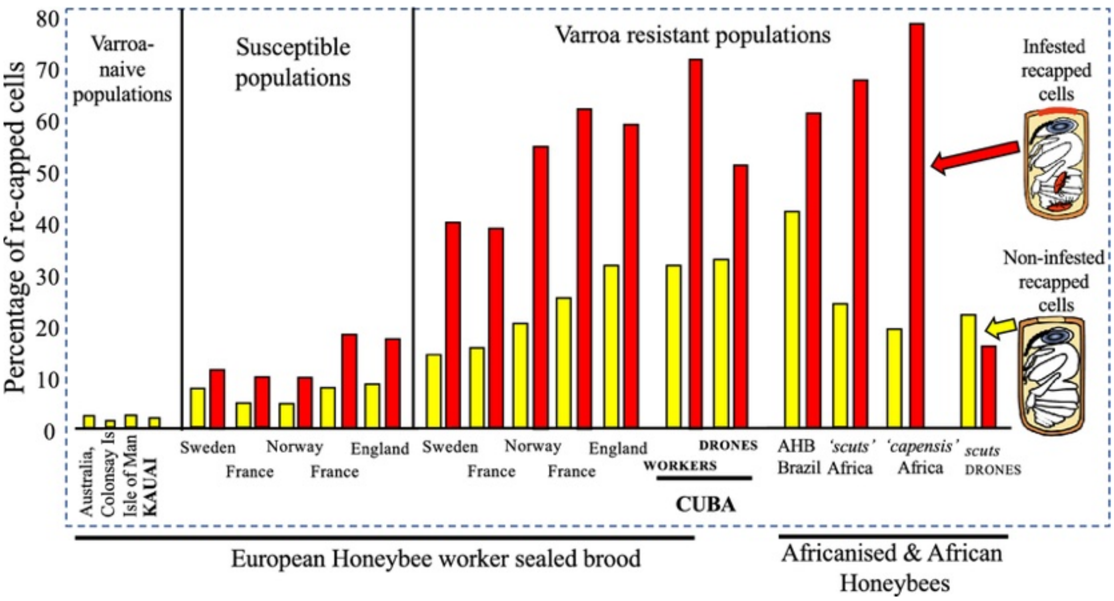

Figure 8. Percentage of brood cells uncapped and re-capped by different populations of *Apis mellifera* around the world. Varroa resistant populations uncap and re-cap a significant amount more than Varroa susceptible populations, who still do this a significant amount more than Varroa naïve populations such as Australian bees (Source: Luis et al., 2022).

Natural selection

Vast populations of feral hives around the world have either undertaken a genetic shift to mite resistant traits or died out completely as Varroa has swept across every beekeeping continent over the last 70 years. Figure 9 shows known Varroa resistant feral bee populations across the world, a small but slowly growing cohort. The potential appearance of Deformed Wing Virus or a similarly virulent mutation of an existing virus in Australian bees may have a significant effect on how fatal Varroa will be for our vast reserve of feral hives. Such a large population crash has the potential to wipe out valuable genetic diversity. Small Hive Beetle pressure will be a compounding problem as dying feral hives provide the perfect breeding ground for a SHB population explosion.

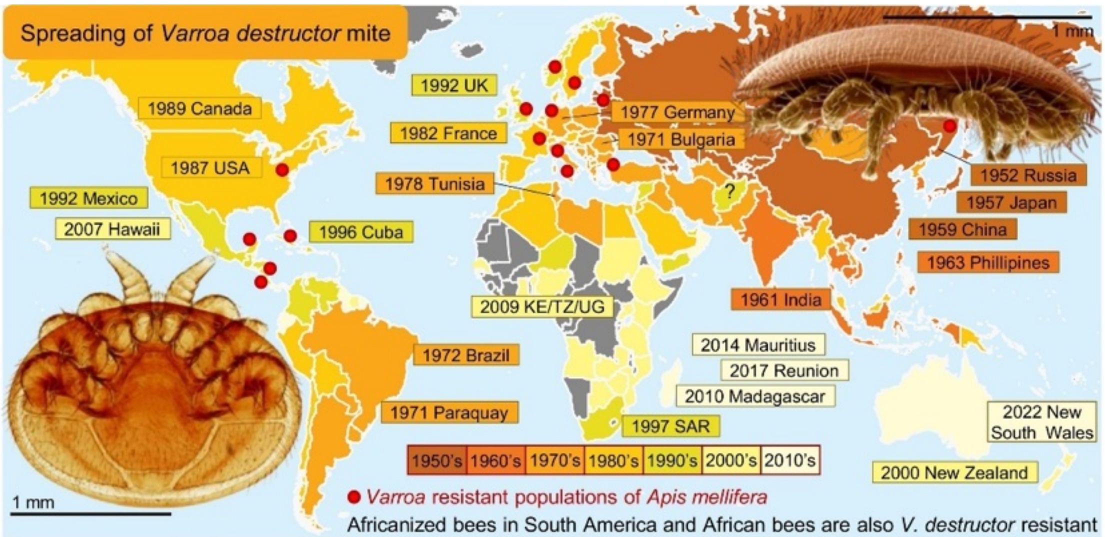

Figure 9. The spread of Varroa destructor throughout the world, with some known varroa resistant bee populations marked (Source: Krejčí et al., 2023).

Both beekeepers and feral hives in subtropical Hawai'i, USA, were devastated when Varroa arrived on Oahu in 2007 and SHB in 2010. However, 17 years later the island of Oahu has 72% of surveyed managed colonies mite resistant (Martin et al., 2023). This island has a similar climate and beekeeping culture to the subtropical Northern Rivers region of north east Australia. There was no dedicated island wide drive for Varroa resistance as happened in Cuba. These beekeepers almost all used chemical controls for Varroa at least for the first decade, which would have slowed the genetic shift of the overall population. Many beekeepers were still treating for mites during the study, not realising that their bees had over 40% recapping rates indicating Varroa resistance (Martin et al., 2023).

The feral bees of Arnot Forest in New York State, USA, are another well studied group of survivors. They were surveyed in 1978 and again in 2002, with Varroa having arrived around 1987. The forest had the same density of bees present before and after, around one hive per square kilometre. Further testing led Seeley (2006) to conclude that these bees were Varroa tolerant rather than resistant. In most other places the natural Varroa survival rate was low for bees. *Varroa destructor* was deliberately introduced to Santa Cruz Island off California for feral species control, with the first of three releases in December 1993. Colony mortality remained the same for two years, then by January 1998 all 117 remaining hives perished (Wenner et al., 2000). There is no guarantee that any one population of bees will hold Varroa resistant genetics.

Queen selection

Actively selecting Varroa resistant queens and removing unsuitable queens promptly will facilitate a stable transition from a naïve population of bees to a Varroa resistant one. Cuba has 221,000 Varroa resistant hives managed by 1,900 beekeepers. Cuban beekeepers achieved Varroa resistance in 5-8 years. Hives average 45-70kg of honey annually, with 80% recapping hygienic behaviour. Bees have been genetically tested to prove they are *Apis mellifera* with no Africanised genetics (Luis et al., 2022).

Mite resistant queens will provide the best outcome for commercial beekeepers defending Australia’s food security through pollination. Around the world various methods have been developed for queen breeders to select for Varroa resistant traits. Popular methods include the Harbo Assay, pin prick brood, freeze drying brood, UBeeO scent and VSP scent. For links to further information see Appendix 1. Dr Fanny Mondet (2025) recommends testing late in the season after most mite reproduction has moved from drone brood to worker brood.

The cost and effort of selecting for Varroa resistance in queens is a major constraint on queen breeders. Beekeepers may be unwilling or unable to pay the value of these queens. If the cost of chemically treating a hive for a year is less than the cost of requeening with a resistant queen, beekeepers may make an immediate business decision to continue chemical treatment. Resistant queens may still require some Varroa control, particularly in bad years. Many beekeepers have an incorrect black and white idea that a bee is either Varroa resistant or not Varroa resistant. Extensive education is needed for beekeepers to understand the reality of pursuing a new genetic direction and the need to support early stage progress towards a sustainable future.

Bee biology is the next constraint. A queen who flies 7km to open mate up in the air with a dozen or more drones of her choice presents exponentially more challenges than those faced by the local cattle stud. These can be overcome by artificial insemination (AI). AI is not a widespread skill amongst beekeepers but training is available through Tocal College in NSW. A visually Varroa resistant hive with sister groups from 12 different drones may have Varroa resistant genetics in only a portion of eggs laid. The queen breeder then has no way of knowing which egg has what genetics when grafting. This can be overcome by single drone insemination of the queen. The queen will have less laying longevity but, provided her workers are Varroa resistant, she guarantees all her eggs have the same resistant genetics for grafting selection. This method is used by the Varroa Resistenz 2033 Project, which aims to have Varroa resistance widespread across Europe by 2033.

A slower but simpler way for queen breeders to contend with open mating is to flood the area with their own drones. This method is used by Randy Oliver in the USA, handing out queen cells to local recreational beekeepers to ensure the desired resistant genetics are dominating the area. Slightly more complicated is the Horner method of only releasing queens and drones after the local stock have headed back to their hives for the afternoon (Büchler et al., 2024).

Accelerating this process as much as possible will give our bees a crucial advantage if Deformed Wing Virus, viruses of similar impact, or Tropi mite spreads in Australia. Locally adapted queens may be best for breeding Varroa resistance (Guichard et al., 2020). Migratory beekeepers exposed to collective events like almond pollination will face the greatest challenges. Note the case studies below are areas where Varroa invasion was over two decades ago and there is usually a minor winter brood break.

Steve Riley at Westerham Beekeepers Club, UK
The Honey Bee Solution to Varroa (2024), (highly recommended reading)
Westerham Beekeepers Club have used the latest research and expert advice to gain 130 open mated hives not requiring Varroa management for over seven years.

Hive husbandry practices
Mostly National hives. Beekeepers follow Torben Schiffer and Tom Seely's work on natural hive defences such as roughening the inside of hives to encourage propolisation, using natural beeswax foundation and no chemical miticides that would damage hive ecology such as pseudoscorpions.

Mite threshold monitoring
Hives with potential breeder queens are monitored using a base board beneath an open mesh floor. Notes are taken on uncapping and recapping of brood frames (Figure 10A). On the base board notes are taken on mite fall (noting numbers of adult or juvenile) and fallen chewed out pupae exoskeleton pieces (Figure 10B). Base board inspections happen every two to three days, weekly or two to three days per month to record findings depending on the beekeeper. The wealth of information found needs to be correlated to the seasonal activities of the hive.

Queen selection method for Varroa resistance
A good breeder queen will have brood with many recapped cells (a learned skill to see), pop holes and clusters of uncapped cells at the pink eyed stage where bees have been searching for Varroa (easy to see and record). In south east England an average mite drop of five per day (averaged over the year) was breeder queen material, six to ten okay and over ten requeened. This was similar to mite drop found in a French study of Varroa resistant hives when adjusted for brood area.

Mite control method
A single frame queen isolator trap cage was used for Varroa control until sufficient resistant queens were available to no longer need Varroa control measures.

Long term findings
Mite drop in resistant colonies is trending downward over time as queens improve.

Figure 10. A. Brood activity of a hygienic hive. B.Mites and pupae parts on the base board. "The Honey Bee Solution to Varroa" (Riley, 2024) is highly recommended reading for details.

Randy Oliver at Golden West Bees, USA
www.scientificbeekeeping.com (highly recommended reading)
Golden West Bees is a family owned and run operation of 1000-1500 hives. These bees perform almond pollination in California. They face some of the worlds most challenging conditions for bees, crossing antennae with 2.3-2.6 million hives that may hold unknown foreign pathogen and mite risks.

Hive husbandry practices
Standard Langstroth boxes, though noted that good beekeeping is not limited to a hive shape. Hives have plenty of honey stores, full sun unless ambient temperatures are over brood temperature, boxes dry and draft free with access to quality pollen sources.

Mite threshold monitoring
Regular monitoring using a soapy water wash of 300 bees (1/2 cup) from the first frame adjacent to the brood.

Queen selection method for Varroa resistance
Zero mites in a soapy water wash five times in a row over several months.

Mite control method
Organic chemicals, splitting, drone trapping and mite resistant queens are used to control mites. Extensive experimental testing is done on these methods as part of mite control. No synthetic miticides have been used since 2001. Mites are controlled proactively early in the season for best success.

Long term findings
Half of Golden West Bees hives no longer required treatment in 2024.

2. Hive husbandry

Hive husbandry is a broad and holistic process. This has been divided into apiary set up (Figure 11), hive design (Figure 12), management within the hive (Figure 13) and beekeeping practices (Figure 14). Together these features can contribute to or prevent the spread of mites and viruses or the contamination of honey and wax even once the best mite resistant queens are selected. Some measures will increase general hive health while others target Varroa mite. Some suggestions are mutually exclusive, for example removing hiding places for SHB or leaving them for pseudoscorpions. Which methods to apply depends on exact goals, resources available and scale of beekeeping. Any beekeeper can potentially lower mite loads by 10-14% by using a screened bottom board (Jack and Ellis, 2021). These are already found in many hives with SHB. Any hive can be encouraged to make their own in built medicine cabinet. To do this standard Langstroth boxes can be roughened on the inside walls or, if treated and painted, have mesh stuck to the walls to encourage a propolis envelope around the colony. This colony level immune system lowers levels of pathogens including AFB and chalkbrood. Propolis emits volatile compounds that reduce microbial activity (Borba, 2016). There are successful exceptions to every point below, at backyard through to commercial scale. A hive or apiary which is conveniently set up for good hive health and management practices allows for efficient integrated pest management.

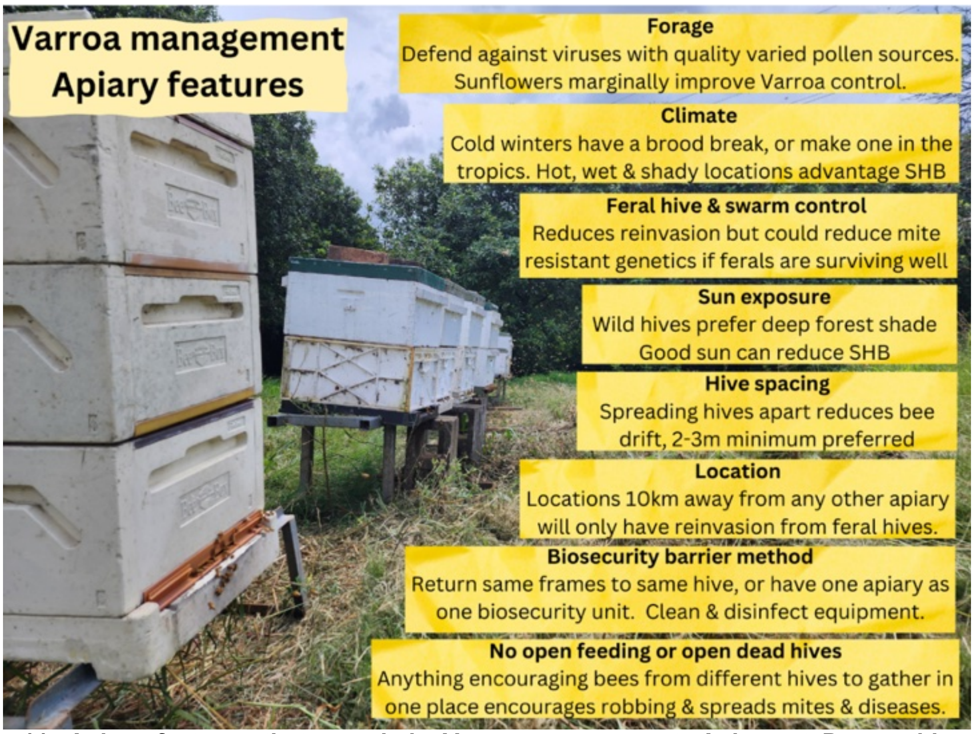

Figure 11. Apiary features that may help Varroa management. Apiary at Dorroughby, NSW. (Source: Author)

Figure 12. Hive features that may help Varroa management. Note some are mutually exclusive. Each beekeeper will make their own choices. Michael Brown in apiary at Newrybar, NSW. (Source: Author)

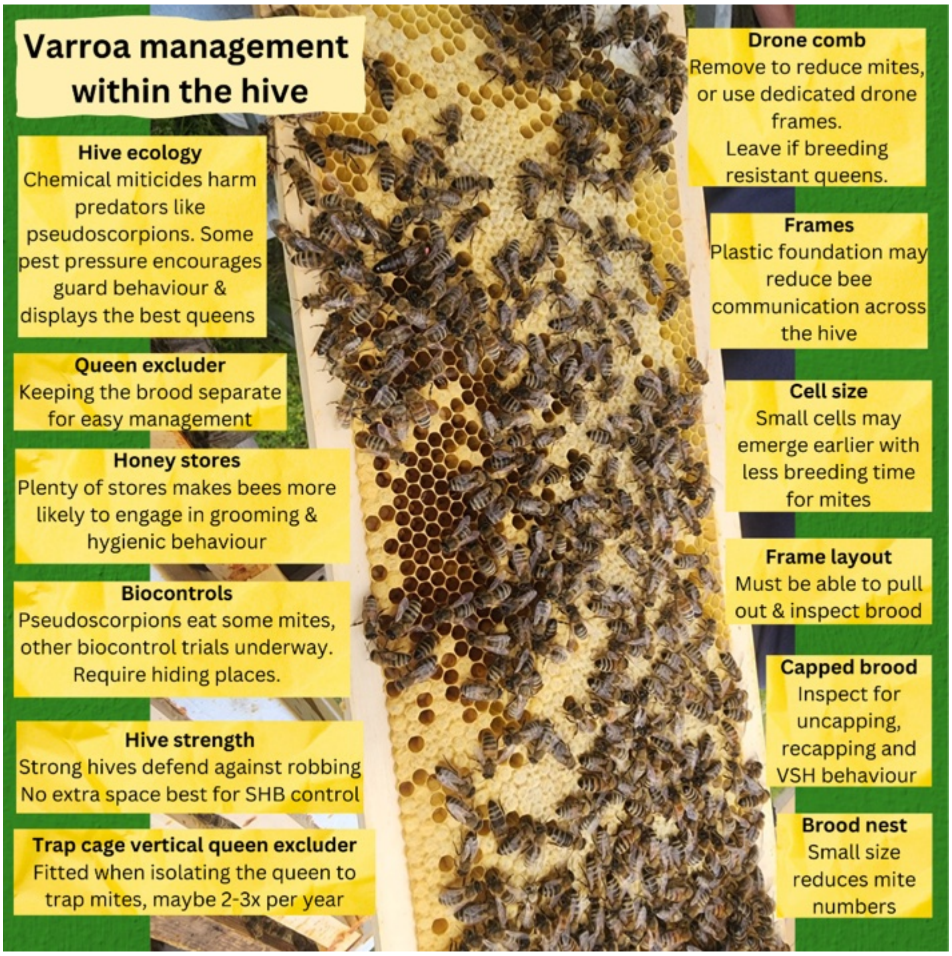

Figure 13. Practices within the hive which may help Varroa management. Hive at Swedish University of Agricultural Sciences, Uppsala. (Source: Author)

Figure 14. Beekeeping practices are not limited to hive husbandry but deserve mention in this holistic overview of Varroa management. J. Morrison and L. Edwards at McLeans Ridges, NSW. (Source: Author)

3. Mite threshold monitoring

Monitoring Methods

All possible measures have now been taken for the hive to manage Varroa mite with minimal beekeeper intervention. The beekeeper still needs a way to know when mite numbers have exceeded the ability of the hive to self-manage. This is important not just for hive survival but as proof of how each queen is performing at managing Varroa. There is ample information available online describing each mite monitoring method. Be aware many sources will dictate which methods are suitable or unsuitable with no context. Consider the location and climate of the beekeeper presenting the method, as well as whether mites have stable numbers in their area.

> Once the apiary has Varroa, the NSW DPI recommends monitoring monthly (except during chemical treatment) using an alcohol wash or soapy water wash. A sugar shake is not recommended in humid areas or on a honey flow.
>
> Monitor all hives in an apiary with up to 10 hives.
>
> Monitor a minimum of 10 hives in a larger apiary. Include colonies from the centre as well as the outer edges of the apiary (Frost, 2024).

The most common mite monitoring methods (links to full descriptions in Appendix 1):

1. Alcohol wash (Figure 15A). Consistency is key. Use a measured half cup of bees.
2. Mite drop on a baseboard. Also demonstrates hygienic behaviour such as pupae removed. Roll a light layer of oil or Vaseline on the tray and insert it under the mesh base board for seven days minimum. Divide mite numbers by days for daily drop. To account for the number of mites in sealed brood and on adult bees, multiply daily mite drop:
   x400 May to August
   x30 November to February
   x100 September, October, March and April

   These numbers are from temperate climate UK (National Bee Unit, 2024) with the seasons adjusted for the southern hemisphere. The app Apizoom is capable of counting mites on a base board, but currently requires a camera. Current smart phone cameras are not yet high enough quality. Natural mite fall may not be accurate enough for the high variability initial invasion phase of Varroa.
3. Soap wash. Use low suds soap. Seen as less flammable than alcohol washes near a smoker.
4. Sugar shake. High humidity is a problem, accuracy is variable between users.
5. Drone uncapping. Use an uncapping fork on purple eyed drones. Easy to verify presence or absence of mites. This can only give accurate mite numbers if a minimum of 300 purple eyed drones are forked out (National Bee Unit, 2024).
6. Carbon dioxide. Generally unpopular due to low accuracy.
7. Visual inspection. Not accurate at all by eye (Figure 15B). The BeeScanning app may be effective. Mite numbers are well out of control if visible on many bees.
8. Mites in cell count. Measure a 10x30 block of worker brood cells. Uncap, pull brood and count mites to very accurately determine what the future holds for your mite numbers. Very slow and labour intensive, used to verify concerning results from another method.

Not monitoring at all is a common practice. Not surprisingly the result is often area wide hive deaths. This happens when groups of beekeepers are all relying on someone else to monitor and pass on information. Eventually either a bad year for mites happens or mites develop resistance to a commonly used synthetic miticide. By the time mites are visible on bees it may be too late to save the hive. Table 4 notes the main features of the commonly used methods listed above.

Table 4. Mite monitoring methods commonly used around the world, in approximate order of accuracy. X is a no and ✓ is a yes for that method on the feature noted. The table assumes brood all year but limited drone brood and that winter has some warm enough days to open the hive. (Source:??)

Method	Hive not opened	Any time of year	No bees killed	No risk to queen	Little time taken	Detects reinvasion	Detects reproduction	Accuracy out of 5	Notes on use
Open 300 brood cells	X	✓	X	✓	X	X	✓	5	Uncommon, tedious, use when concerned for future mite numbers
Alcohol wash	X	✓	X	X	ok	✓	X	4.5	Accepted standard for convenience and accuracy. ½ cup of bees is approx. 300
Soap wash	X	✓	X	X	ok	✓	X	4	Some find it harder to count mites, no flammability issues
Base board count	✓	✓	✓	✓	✓	X	✓	3.5	3 days per month or weekly, can use sticky mat or can roll oil on.
Sugar shake	X	✓	X	X	ok	✓	X	3-4	Variable accuracy between users. Bees may die after shake anyway
CO_2	X	✓	X	X	ok	✓	X	3	Use alcohol wash container. Accuracy variable.
Drone uncapping	X	X	X	✓	X	X	✓	2	Fork out 300 purple eyed drone pupae; hard to determine correct age to fork
Visual inspection	X	✓	✓	✓	✓	ok	X	1	Verify high mite loads; unusually small brood nest, inspect underside of bees
No monitoring	✓	✓	✓	✓	✓	X	X	0	Treating same time each year or no mite intervention

Figure 15. A. Four varroa in an alcohol wash at McLeans Ridges, NSW. Note the size, distinct oval shape, maroon colour and smooth edges. The methylated spirits can be tipped onto a paper towel and scanned with a magnifying glass if needed. B. Varroa mite on a bee at Thomas Van Pelt's apiary near Wangen, Germany. This shows how difficult mites are to spot by visual inspection. (Source: Author)

Comparing results between methods

Beekeepers who wish to use a less accurate method regularly can lift their accuracy by checking against another method. For example, many beekeepers who monitor with a regular sugar shake also did an alcohol wash sometimes to check accuracy (Wakeford, pers.comm., 2023). Below is an example of local beekeepers collaborating on Varroa control timing even though they use different monitoring methods. They work together to avoid being the unlucky recipient of someone else failing to monitor until there is a major mite problem. Their varied methods also demonstrate the need to understand where mites are in the hive at different times of year.

Steve uses base board counts of mites for his mite resistant queen breeding program. Michelle uses soapy water washes as she does not have screened bases. James removes drone pupae to count mites and just compares against an alcohol wash sometimes.

Throughout the year Steve is following the southern hemisphere version of the brown and light blue trends for mites in brood below (Figure 16). Michelle is following the southern hemisphere version of the gold and darker blue trends for phoretic mites. James is following only the darker brown trend for mites in drone brood, which will be a much longer area time wise in tropical climates. The mite count that each will come up with will be very different. The combined trend they come up with throughout the year will be specific to their local area.

These neighbours wish to control mites at the same time to reduce reinvasion risk. How do they compare their mite loads? The easy way is to pick one method and sample all three apiaries when all beekeepers expect to be close to their threshold. An alcohol or soapy water wash will be high accuracy and easy for everyone to do regardless of hive set up. Once the first beekeeper reaches the threshold limit for mite numbers that they have decided on, all three will start to use whatever control method they have chosen. This will reduce the chance of mite reinvasion from a neighbouring apiary soon after mite control is undertaken.

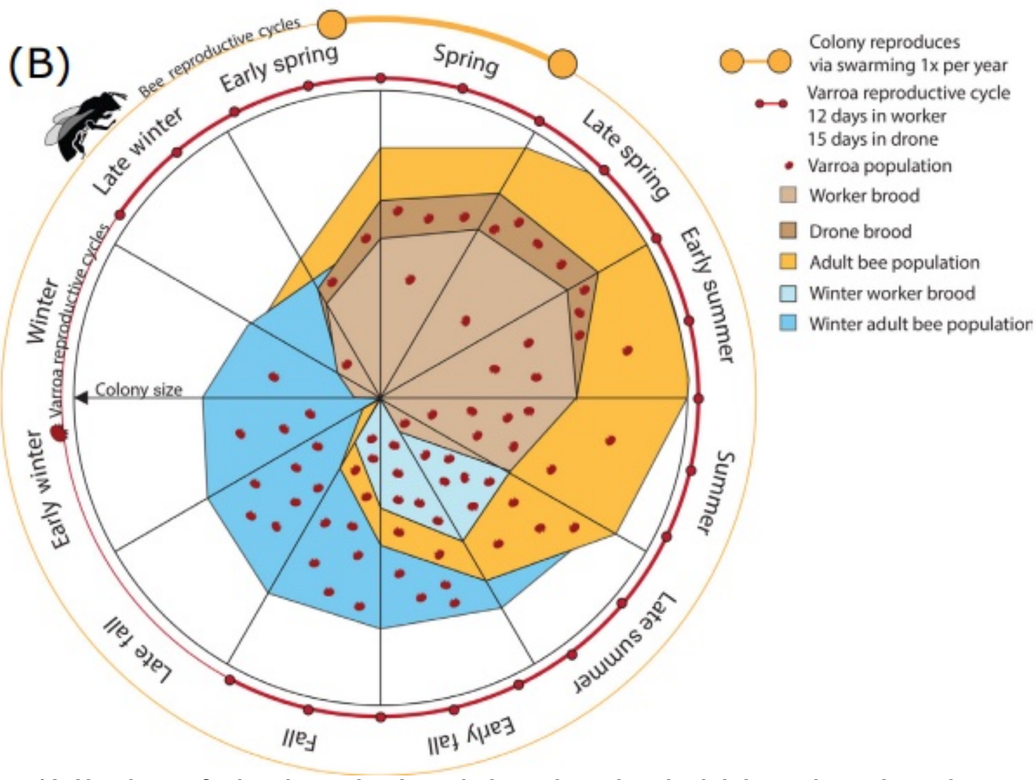

Figure 16. Numbers of mites in worker brood, drone brood and adult bees throughout the year in the northern hemisphere (Source: Traynor et al., 2020). Beekeepers will need to build their own picture for their local area.

Each beekeeper needs to select a method they can easily and accurately repeat on a regular basis. Understand what the method is showing and is not showing about colony wide mite numbers. Build a picture of the local regular mite year to show which queens are beating the trend, which are failing and when mite control action is required. All these methods are used by successful beekeepers.

Determining threshold limits for action

By the time the bees have absconded or died it is too late to decide! **Photos on the internet are misleading; by the time you can see mites on bees it is too late.** Only consistent monitoring with an accurate method will tell you when mites arrive, when mite numbers are going up and when it is time to act. Figure 17 below shows the relationship between bee and mite numbers over a temperate year. Tropical beekeepers can make a brood break to gain the same minimal population phase effect on mite numbers. The mite population curve follows behind the bee population, meaning that mite numbers continue rising when bee numbers are falling in autumn. This is when many mites will enter the dropping number of brood cells, producing nearly as many mites on less bees. This demonstrates that the beekeeper will need to act early in the year back before the 6 mites per 100 bees to avoid the hive being overwhelmed when bee numbers are down and mite numbers up. The hive is unlikely to survive 35 mites per 100 bees in autumn (Oliver, 2006).

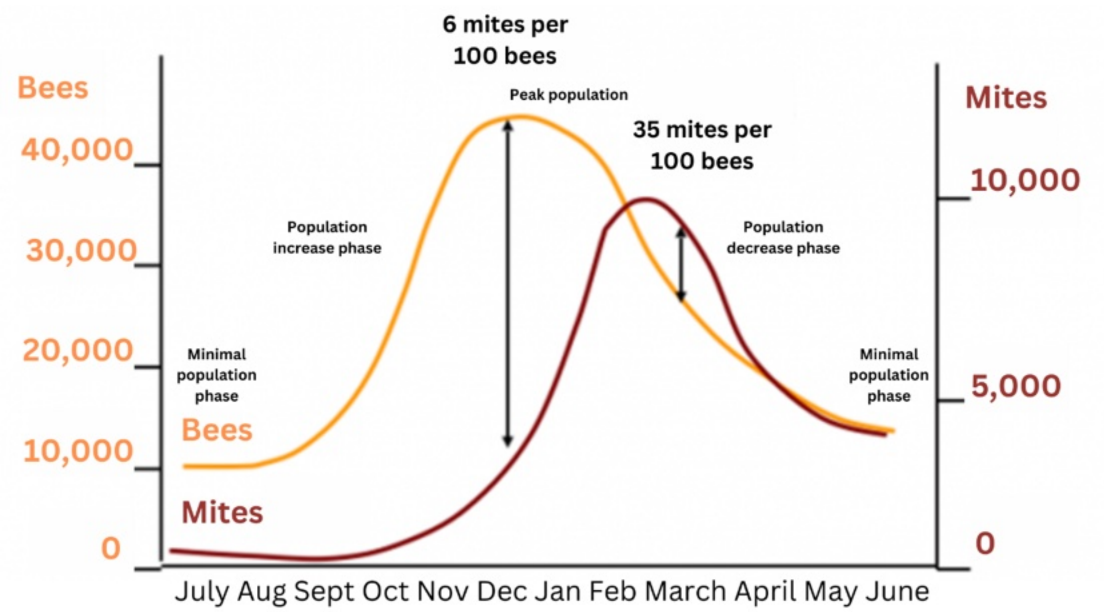

Figure 17. Simplified mite and bee population dynamics in a temperate climate hive (modified from Source: Oliver, 2006). In tropical climates the mite population peak will still follow behind the bee population peak but both populations may stay high all year, causing a quicker hive crash.

Points to consider when selecting a Varroa control action threshold:

1. Mites per wash or sugar shake divided by three is the hive mite percentage. For example, six mites in a ½ cup wash or shake (300 bees) divided by three is a 2% mite infestation in the hive.
   Pick one and check which method others are using when comparing results.
2. NSW DPI has seasonal treatment threshold recommendations (Table 5).
3. Using base boards for natural mite fall count may not be a sensitive enough method during the initial invasion period. Hives may abscond by the time high mite numbers are seen dropping out of brood. Control mites before reaching 1000 mites total in the hive (see Monitoring Methods above to determine this). Mite fall is not accurate when the hive is broodless or collapsing from Varoosis/PMS (National Bee Unit, 2024). General UK advice is to treat urgently if daily drop is over 30, treat soon if daily drop is over 10 (Stainton and Ponting, 2020).
4. If uncapping 300 drone cells, control varroa urgently when over 5 mites per 100 drone brood are found and monitor closely when over 3 mites per 100 drone brood are found.
5. What has happened in NSW already (Taylor-Brown, pers.comm., 2025)
   - The NSW DPI threshold limits may be suitable expectations for controlling mite numbers using organic acid treatments
   - Hives may start looking unhealthy at around 40 mites per 300 bees
   - 40 mites per 300 bees may be too high in mites to try to save with organic acid treatment but recoverable by synthetic chemical treatment
6. The initial invasion period may bring fast and extreme volatility of mite numbers. 600 mites have been seen in a 300 bee wash of a hive which appeared healthy at the time. Viral loads can take years to build up in bees. Deformed Wing Virus has not been detected on *Apis mellifera* in Australia at the time of writing. Survivable mite numbers may decline steeply as viral loads build up in bees.

Viruses are less impactful and less likely to mutate into a more virulent or deadly strain when mite numbers are kept low.

7. Alcohol washes or sugar shakes in mite resistant bees of subtropical Hawai'i commonly had 3-7% mites after 15 years of Varroa, higher than the mainland USA treatment threshold of 1-2%. DWV is endemic across the USA including Hawai'i. Thresholds tend to become higher and wash numbers lower in resistant bees over time (Martin et al., 2023).
8. Varroa resistant queens may still require Varroa control assistance at a lower threshold to protect them from being overwhelmed and absconding in the invasion phase.
9. Randy Oliver has made an interactive Varroa population model, discussed further in Part 3. He advocates for early season action, with a 1-2 mite threshold in spring, maximum of six later in the season and zero in autumn.

Table 5. NSW DPI treatment thresholds. NSW DPI requires beekeepers to report mite numbers every 16 weeks, control mites if you reach the threshold and keep records of thresholds and treatments (Source: Frost, 2024).

Colony Phase	Varroa %Wait – immediate control not needed	Varroa %URGENT – Control immediately
Dormant	**Under 1%** (less than 3 mites found)	**Over 1%** (3-5 mites found)
Population Increase	**Under 2%** (less than 6 mites found)	**Over 2-3%** (6-9 mites found)
Peak Population	**Under 2%** (less than 6 mites found)	**Over 3%** (9+ mites found)
Population Decrease	**Under 2%** (less than 6 mites found)	**Over 2-3%** (6-9+ mites found)

4. Break the reproductive cycle

The hives have the best resistant stock the beekeeper can find. The beekeeper has done what they can to disadvantage mites and advantage bees in all hives. Monitoring now shows that a threshold has been reached and mite numbers must be reduced for the safety of the bees. The first concern is not for the adult bees. The greatest risk is to the pupae developing under capped cells who will emerge damaged and less able to play their role in supporting the hive. This is where fertile foundress mites are multiplying, like the invisible iceberg that you can only see the tip of above the water. This is also the one place all mites must go to reproduce. If or when Tropi mites reach Australia brood will be not just the starting place but the only effective place to act (Véto-pharma, 2024).

Brood breaks and biotechnical control methods are an entire Nuffield study in themselves. This is an exciting area of future development! These methods have been proven to reduce Nosema, acute bee paralysis virus and chronic bee paralysis virus. More research and trials are urgently needed for Australian beekeepers seeking chemical free methods of controlling Varroa mite, particularly on commercial scale. This is a long gradient of methods which can be easily adapted to suit the beekeeper and the Varroa resistance level of the bees. Hyperthermia (heating) and chemical treatment with formic acid, the only chemical control known to penetrate capped brood, are also covered here.

Considerations and options available using Varroa control by brood manipulation:

- Any method caging the queen can be used in conjunction with queen rearing, as queen cells can be kept in the hive without destruction by the existing queen
- Brood manipulation methods can be used as part of seasonal swarm control
- Isolate the queen two to three weeks before the last honey flow to increase yields by up to 20% through maximising foragers with no brood to care for (Lyson, n.d.)
- One frame of eggs and larvae can be left in the hive at the end of any suitable method to collect phoretic mites searching for brood. Remove once capped.
- Up to 12% of hives may have two queens. If eggs are seen outside a queen cage or trap frame, search for a second queen. Cage her as well and start the time required from day one again (Van Pelt, pers.comm., 2024).
- Vertical queen excluders can be used instead of isolator cages to limit laying area

Trapping mites in drone brood

Removing capped drone brood is one of the most popular methods to reduce mite numbers. If given a choice four out of five mites will enter drone brood. 1.5 daughter mites will emerge from worker brood compared to 2.5 from drone brood on average. This method can lower mite numbers by 46% in spring, or 89% if done twice in summer one month apart in the centre of the brood nest (NSW DPI, 2024). There is no evidence that drone brood removal adversely affects hive health or queen mating success (Stainton, 2022). Queen breeders of mite resistant bees will want all drones produced working the local drone congregation area, so they will select alternative strategies.

1. Use an empty frame with no foundation comb, wired or unwired. Mark the top "D." Nail in a piece of timber dividing it in half (either direction) so half at a time can be cut out as it is built out (Figure 18A). Alternatively an ideal or WSP frame can be used in a full depth box so drone comb is built along the bottom. For top bar and other sized hives use your usual method of having bees build out a new frame. Green plastic frames with drone brood foundation sizing already embossed on are available. Beeswax foundation embossed with drone cell sizing is also available.
2. Insert the frame second in from the edge of the brood in time to be built out for prime drone season in spring. Alternatively place in the super to be built out first.
3. MAKE SURE THE FRAME IS REMOVED 10-20 days after eggs are laid to avoid making a mite factory. Feed it to chickens, melt it down, freeze for 48 hours and return to the hive or dispose of the frame in any way that bees cannot access it.
4. Alternatively, fork out drone pupae in brood with an uncapping fork (Figure 18B).

Figure 18. A. A drone frame built out. Dr Ralph Büchler's apiary, Germany. B. Uncapping of purple eyed drone pupae to remove mites (circled). Karina Tomtlund's apiary, Sweden. (Source: Author)

Trapping mites in worker brood

1. Shook swarm with brood removal: no need to find the queen

Bees naturally swarm to leave behind parasites and pathogens in brood comb. Removing all brood is a significant drain on the resources of the hive, but if done at the right time of year when resources are available hives recover quickly and are not disadvantaged overall for the season. The hive should be fed syrup if resources or stores are limited. A split can be made with the capped brood provided immediate mite control is undertaken in the split (Uzunov et al., 2023).

- Remove all capped brood from the hive, leaving one frame of uncapped brood
- Replace with foundation or, if available, built out stickies/wet frames
- Shake all bees including the queen onto the new frames
- Return nine days later to remove the now capped off brood frame, which has collected phoretic mites
- Alternatively, some beekeepers treat with oxalic acid while the hive is broodless

2. Trap comb: the queen's "summer holiday home" isolator

This is a slower, more gentle method capable of removing 90-95% of the mites in a hive. Single, double or triple frame isolators are available (Figures 19-21). Beekeepers can easily make a single frame version at home. Alternatively, a vertical queen excluder can be purchased or made to restrict the queen provided the brood box is evenly shaped with a queen excluder which seals well on top. Single frame isolation requires more precision timing, whereas two frame isolator trapping may be more forgiving for the beekeeper. Either of these methods is ideal for controlling pathogen build up by replacement of three older brood frames annually (Uzunov et al., 2023).

Figure 19. A. Thomas Van Pelt demonstrating a three frame queen isolator at a bee club meet in Wangen, Germany. Once located, the queen is safely kept in a queen clip during set up. Replacing the queen could be done instead of releasing her at the final stage. B. Single and double queen isolators plus a half frame queen cage on display at the meeting. (Source: Author)

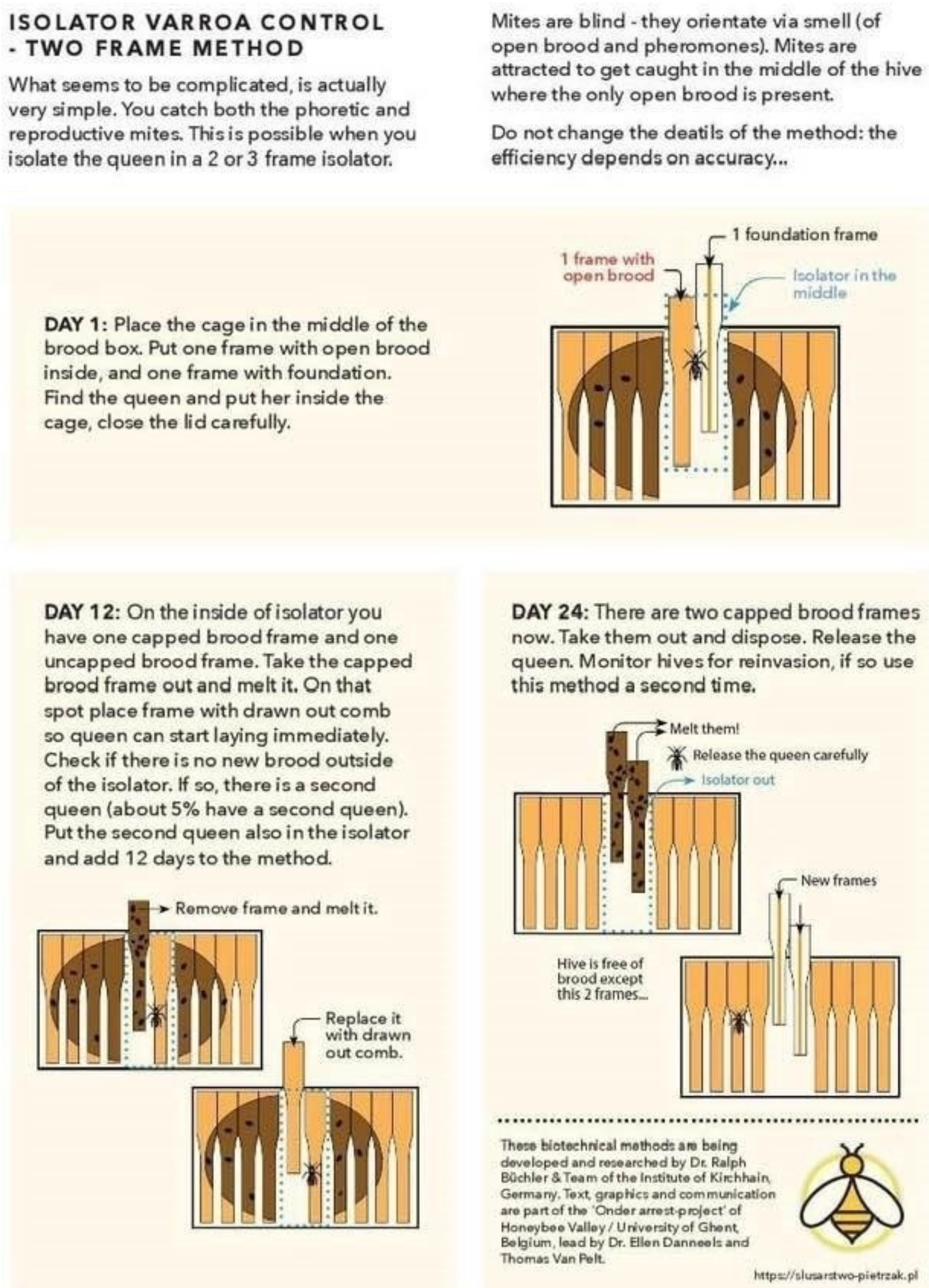

Figure 20. The label instructions for the two frame queen isolator. This method has three visits 12 days apart and is recommended as the most convenient mite trapping method (Source: Van Pelt, pers.comm., 2024). A drone frame could be used instead of the frame with foundation.

Both queen isolators and queen caging can be comparable in efficiency to formic acid treatment (Uzunov et al., 2023). Beekeepers in Germany with a winter brood break completed this process one to two times per year, translating to two to three times per year for Australian beekeepers with no naturally occurring brood break. It is unknown whether this method will be effective during the initial invasion phase. Aim for a time of year with naturally lower brood numbers. Frames of capped brood can be melted down, frozen for 48 hours and given back to the hive, or placed in a dedicated mite receival hive or apiary in an isolated location. A queen isolator, chemicals, hyperthermic treatment or other method of choice can then destroy or trap emerging mites in the receival hives, leaving only minimal frames to melt down (Büchler, pers.comm., 2024).

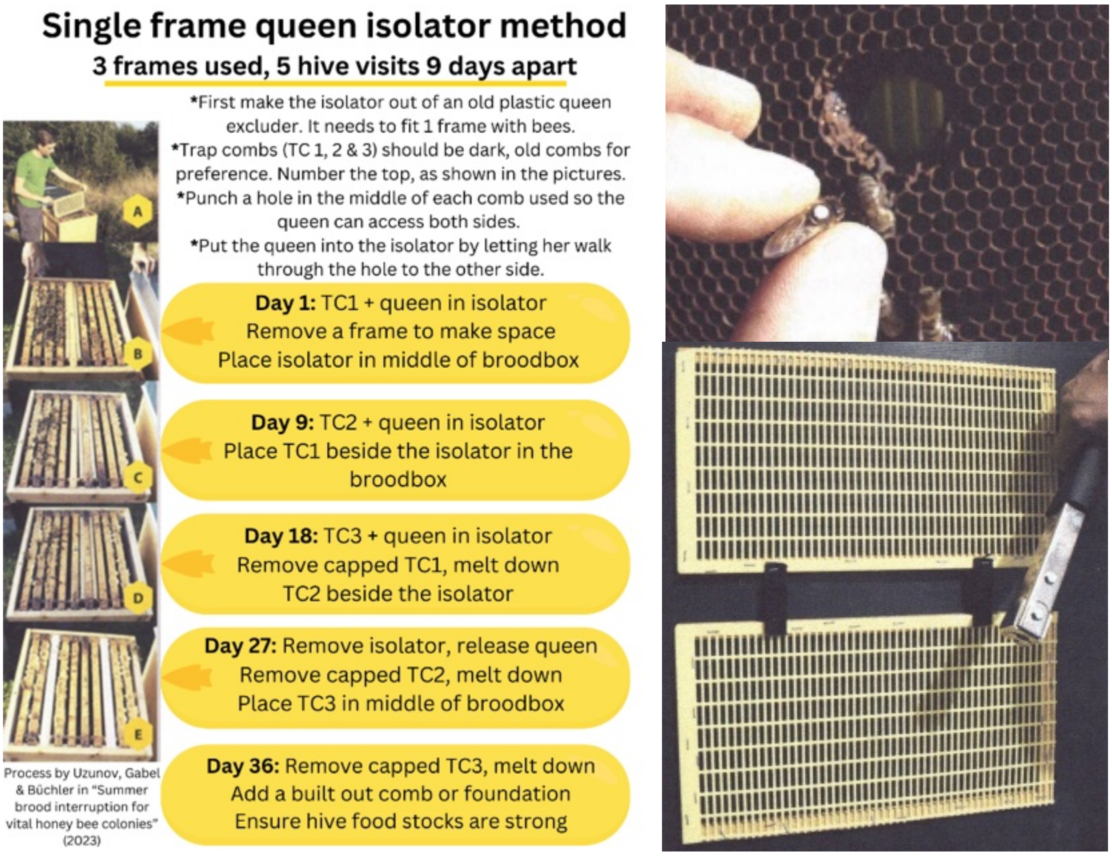

Figure 21. A. Procedure for the single frame queen isolator. B. The queen added to the isolator through a hole punched in the frame. C. Making a single frame isolator at home. (Source: Uzunov, Gabel and Büchler (2023)). This is highly recommended reading as the full details are beyond the scope of this report. Büchler uses vertical queen excluders instead of a cage to restrict the queen.

Suggestions for finding the queen

Many beginner beekeepers may hesitate to use these methods due to difficulties finding the queen. However, this is a skill worth investing in. Some suggestions:

- Use a queen excluder to limit the area needing to be searched
- Check the underside of the queen excluder when it is removed
- Remove the second frame in, check it carefully and put it beside the hive. Then work methodically from one side of the hive to the other, immediately checking on the next frame and box sides every time a new frame is lifted
- Inspected frames can be placed in a spare box to make checking the base and sides of the brood box at the end easier
- Check very carefully for her on frames with eggs
- Mark the queen using a non-toxic, water based paint pen and queen mark cage
- Use a queen clip to hold her in while setting up the isolator or other method
- If all else fails and she must be found, remove the brood box to a nearby bench about a metre away. Wait an hour on a sunny day if possible. This will allow foragers to fly to the original brood box position, leaving less bees to search through. Carefully check each frame as above.

Experiences from Ballina Honey after six months of controlling Varroa in the subtropical Northern Rivers using only two frame isolators January-July 2024:

- We requeened with queens from Rockhampton Bees because these queens are from a high SHB pressure area and are in the varroa resistant queen breeding program using UBeeO testing.
- Ensure the isolator you buy has the correct size bars to allow workers to enter and leave while containing the queen. Some isolators on the market are designed for queen introduction and exclude all bees.
- Use a queen excluder on top to ensure the isolator cap is held down firmly
- Plug the ends with wax if needed but an isolator too short front to back of the box is unlikely to keep the queen in
- Ensure the isolator you buy fits your box and base. Lyson isolators are excellent quality but were too deep for the wide edge on our Nuplas bases. We used a router to reduce the plastic edge size .
- Check for brood outside the isolator to see if you have a second queen
- Use the isolator while mite numbers are still low. High mite numbers at the start will leave high mite numbers at the end. This data is still being collected but 10+ mites in a wash is too high in autumn. This method struggles with high phoretic mite invasion numbers in the invasion phase.
- Isolators are designed for use in summer when hive numbers will recover quickly. We are using them in a very wet autumn. Despite this our hive losses (around 10% and almost all at one apiary) we attribute to horrendous wet weather around Cyclone Alfred with losses compounded by varroa.
- Feeding a pollen supplement encourages the queen to lay but beware this also encourages Small Hive Beetle
- We will continue trials through spring and summer using two slide in vertical queen excluders to avoid having to locate the queen
- See Appendix 2 for trial results through to 1 August 2025

Brood breaks

Subtropical beekeepers can gain the natural advantage of colder climate brood breaks. Migratory beekeepers in the USA who would have taken hives south into Florida for winter may now take hives north instead to ensure hives start the season healthier after a winter brood break. Longer brood breaks reduce mite fertility for a longer period after the brood break (Gabel et al., 2023).

1. Splitting the hive

Splitting the hive to create a Varroa reproduction break for both hives requires consideration of drones available for mating queens, hive resources available and the timeline in Figure 22A. Swarm season will be most successful (Hersback, 2016). Queens are generally available year round from many Queensland producers. In areas where drones are more seasonal, autumn queens may be insufficiently mated if drone numbers are low. A diversity of drones improves health, survival and productivity of the hive (Oldroyd and Chapman, n.d.).

Considerations when splitting hives:

- For a walk away split the old queen, plenty of young bees, built out frames of foundation (if available), plus preferably some honey stores and pollen are added to a nucleus box. Leave all the brood and remaining bees in the original hive to make a new queen from the eggs available.
- Alternatively, introduce a ripe queen cell (Figure 22B) from a more Varroa resistant hive into a split made 14 days earlier. Check carefully that there are no eggs available to make a queen, and check again for emergency cells when adding the cell. Note that a virgin queen can emerge from an emergency cell 12 days after the split date as the bees will select one day old larva. Randy Oliver splits in late spring, adds a queen cell and treats with OA dribble once the hive is broodless (Dawkins, 2024).
- If the original queen is performing well, her new hive could be given a brood break by using a queen cage described below or she could go into an isolator so that two frames are laid out as trap frames. She could be released nine days later and the capped frames (now full of phoretic mites) removed for melting down. Or any suitable combination of other measures could be used.
- Check that the new queen is laying well by approximately day 27 (continuing the count from hatching on day 16). If she fails to return from her mating flight workers may develop ovaries and start laying. They will only lay unfertilised drone eggs. This is apparent from many eggs in each cell and often not in the centre. Laying workers will rarely accept a new queen.

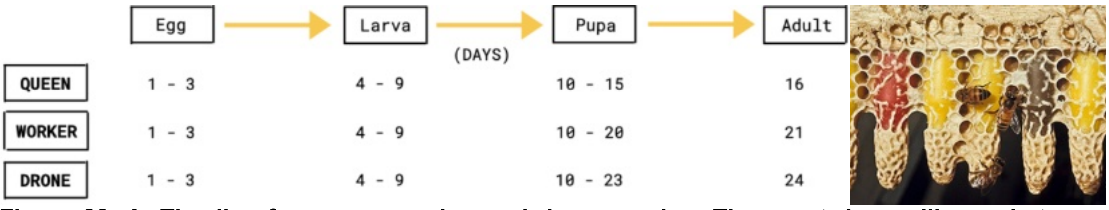

Figure 22. A. Timeline for queen, worker and drone rearing. The exact days will vary between climates and hives (University of Guelph, n.d.). B. Ripe or mature queen cells (Chapman, 2020). The end of the cap is lighter colour and different texture once the workers have decided the queen is ready. Workers will communicate with the queen via vibratory signalling (Source: Hesbach, 2016).

2. Queen caging using a Scalvini or Mascarponi/Mozzato cage

Caging the queen was found to suppress mite reproduction even while she was caged (Gabel et al., 2023). The loss rate on caged queens can be from negligible (two queens out of over 500, provided the hive is not moved or unduly stressed while she is caged) up to around 10% (Van Pelt, pers.comm., 2024). Studies proved that none of these brood manipulation methods were any higher risk to the queen than conventional management, with the lowest queen losses in queen caging (Uzunov et al., 2023). Quality cages can be left in the centre brood frame when not in use for more efficient operation and can go through a frame melter undamaged (Figure 23A). Cages allowing the passage of workers to care for the queen and spread queen pheromone may be best.

Some suggestions for queen caging:

- Catch and cage the queen, to be released on day 25 (Figure 23A and B)
- Mark open brood frames, return nine days later to remove them once capped
- Alternatively, treat phoretic mites with oxalic acid while there is no brood. This gives a 90% reduction in mites
- The queen can be replaced with a new queen. Alternatively, a frame of eggs from a better queen can be inserted for the workers to produce a queen cell.
- The queen cage could have a candy plug allowing her into a single frame trap cage. She could then be released after nine days and the trap frame removed (Büchler, pers.comm., 2024).
- Queen caging is best done when brood is at a minimum, either due to cold or lack of nectar
- Do not move hives with the queen caged. Older queens are also less likely to be successful.

Figure 23. A. Mascarponi queen cage left on a frame ready to use in Thomas Van Pelt's apiary in Germany. B. Home made Scalvini cage, pushed in to the comb midrib (Source: Hesbach, 2016).

3. **Varied strategy: Varroa and Tropi mite control** (Taylor and Goodwin, 2021)

Vietnam has pioneered successful chemical free Varroa and Tropi mite control. Commercial beekeepers have around 500 hives in the dry season but reduce to 50-100 hives during the wet season. Beekeepers run a multi-pronged strategy:

- During the wet season triangles are cut out of frame corners so drone comb is built and capped ready for removal at 15 day intervals
- Rapid splitting at the start of the dry season out breeds Varroa
- During the build up phase brood is removed from one colony and pupae are removed from the first two frames to be capped. The brood is given to another colony whose queen is replaced with a queen cell. Once the new queen begins to lay the pupae are removed from the first two frames of capped brood. Tropi mite is killed by the brood break and Varroa is killed through the brood trapping.
- Whole drone combs are drawn and laid in by strong colonies then distributed to other hives for mite trapping

Hyperthermic treatment

Brood frames can be removed from the hive and heated to 41.5˚C (degrees Celsius) for two hours to kill immature mites. Humidity must also be maintained. Temperatures below this do not kill mites. Longer durations or higher temperatures, even 42˚C, damage drone spermatozoa (Kablau et al., 2020). This method is not common but has been used by some beekeepers in Europe for around 14 years (Figure 24A). 97% of mites in brood cells die one to two days following heat treatment.

A brand name Varroa Controller (Figure 24B) can be purchased which holds either 10 or 20 frames. These machines use 600W and are adjustable to hold frames of different shapes and sizes. Bees hatching while being heated are undamaged, but uncapped larvae does not survive. Anecdotally the Varroa Controller may reduce hive beetle populations, though this still requires extensive study. These units could be used in combination with a queen isolator by heat treating capped brood removed from the isolators. At $6-7,000 these units may be out of reach for a small scale beekeeper but are being considered by many bee clubs as a hire item. Amber Drop Honey near Port Macquarie, NSW, are managing 200 hives chemical free with the use of four Varroa Controllers. Some methods for heating the entire brood chamber without removing frames are available, though this can be stressful for bees as they attempt to cool the hive.

Figure 24. A. Thomas Van Pelt's homemade hyperthermic treatment box in Wangen, Germany. B. A commercially available Varroa Controller in Australia (Source: Varroa Controller, n.d.)

Formic acid

Formic acid is the only chemical known to kill *Varroa destructor* within capped brood cells. This could be important for beekeepers who rely on chemical controls if or when Tropi mite arrives in Australian hives. Formic acid inhibits cellular respiration of Varroa, causing respiratory acidosis. It is unlikely that Varroa will develop resistance to such a complex mode of action (Animal and Plant Health Agency, 2024). In Australia FormicPro® strips are currently the only formic acid use approved. This is currently used under an emergency use permit, with full registration progressing with the Australian Pesticides and Veterinary Medicines Authority (APVMA) (Australian Honey Bee Industry Council (AHBIC), 2024). When handling corrosive chemicals follow the instructions, use the required protective equipment and contact the manufacturer for advice or concerns.

Important considerations when using Formic acid in Australia:

- Only use with daytime temperatures between 10-30˚C, particularly in the first three days of use. Despite this, formic acid and brood manipulation are the only Varroa control methods used by some beekeepers in both Hawai'i (against Varroa mite) and Thailand (against Varroa and Tropi), so a tropical environment does not preclude use. Some tropical beekeepers use formic in hot temperatures by leaving strips in their packaging, cutting both ends off the package to expose the strips then placing them on the brood frames as usual.
- Formic acid is a gas which requires exact humidity conditions in each hive for exact results. Efficacy under ideal conditions is 83-97%. Variable efficacy of 30-70% may be found across the same apiary. Vented bases must be closed to retain gases but a fully open hive entrance is required. Lid vents can remain open.
- Do not disturb or move the hive soon after strips are placed in the hive. However, there is not as much issue with strips staying in the hive past the recommended finish date as there is with synthetic miticide strips.
- Advice found online may vary wildly. Around the world formic acid is administered soaked on meat tray pads or ladies period pads (common in the USA and NZ), or dispersed using a Nassenheider evaporator (common in Europe). These methods and the climate they are used in will have different considerations. Formic Pro is the next generation product of Mite Away Quick Strips (MAQS), both made by Nature's Own Design Apiary Products. These products have a different shelf life, treatment period and storage requirements so advice and results may not be comparable.
- Formic acid is notorious for high rates of queen loss. Losses are 0-12% under ideal conditions but have been much higher for some beekeepers. Formic will delay laying in surviving queens. This problem has been mitigated for some beekeepers by slowing down the rate of release. This is apparent in the Nassenheider evaporator where queen losses may be zero, though general efficacy as used by beekeepers in the field also appears to be lower than FormicPro® despite similar study test results of up to 97%.
- FormicPro® is licenced for use with supers on in Australia, provided honey is not harvested in the two weeks post treatment. Formic acid occurs naturally in honey, particularly darker honeys. Contamination may occur in lighter honeys, but this is not a food safety issue and likely unnoticeable. The non-lipophilic nature of formic acid means there is no contamination of beeswax.
- Formic acid is known for causing bee deaths. Acid in wounds on bees caused by Varroa mite kills bees. Results vary widely, but some beekeepers will not use formic acid because of this harsh effect on bees.
- This product is biodegradable. The expiry date applies more to the slow release casing than the formic impregnated gel within. Strips may be stronger and release quicker if used past the used by date, causing greater mortalities.
- Basic information on how to apply FormicPro® strips in the brood box for Australian beekeepers is in Appendix 1.

5. Remove phoretic mites

For beekeepers in developed nations where consumables are cheap and accessible but labour costs are high, the idea of tucking some chemical strips into the hive and walking away is highly appealing. However, the “too good to be true” feeling is well deserved. Over 70 years of Varroa management, heavy synthetic chemical treatment has become associated with extensive poor bee health outcomes, mite resistance and contamination of honey and wax. Miticides may have toxic synergistic reactions both with each other and with common agricultural fungicides in the environment (Table 6). Application methods may be unsuitable for tropical beekeepers with brood and supers year round. However, Australian beekeepers may be faced with continuous reinvasion events over a number of years as Varroa stabilises in their region. Beekeepers may need to remove many phoretic mites as part of their integrated strategy depending on their needs and goals. Chemical controls approved by the APVMA for Australian beekeeper use are listed in Table 7.

Table 6. Toxic synergistic reactions between active ingredients of common miticides and agricultural fungicides (Source: Binnie, pers.comm., 2023).

Reacting agent	Miticide active ingredient			
	Tau-fluvalinate	Coumaphos	Amitraz	Thymol
Fluvalinate		D	C	B
Coumaphos	D		B	B
Amitraz	C	B		A
Thymol	B	B	A	
Oxalic acid	C	A	A	B
*Pristine	B	A	A	A
*Prochloraz	D	D	A	A
*Chlorothalonil	C	A	A	A
*Pyraclostrobin	B	No info	A	A
(*fungicides)	Toxic synergistic reactions:	**A=mild interaction** **B=notable interaction** **C=significant interaction** **D=alarming interaction**		

Sugar dusting and other mechanical methods

Mechanical methods of removing phoretic mites are less problematic for consumer confidence and perception of bee products. Dusting the hive with powdered sugar (ensure no cornflour or anti clumping agents) or ground rice to dislodge mites and induce grooming behaviour remains generally unproven by scientific study. Despite this it remains more popular than synthetic miticides in the UK. Randy Oliver (2016) compared various studies and beekeeper methods, finding sugar dusting may be more successful than any other method including alcohol wash to estimate the colony mite infestation levels. He found that dusting could reduce mite levels as part of an integrated strategy though not efficiently enough for commercial beekeepers. See Appendix 1 for a link to the full article. The patented Bee Gym, designed to assist bees in grooming off mites, shows similarly mixed or no result (Pattrick et al., 2017).

Table 7. Chemicals registered for control of *Varroa destructor* in Australian hives (Source: AHBIC, 2024).

Australian Honey Bee Industry Council - Varroa Chemical Treatment Table
Current on 18th November 2024 – check www.honeybee.org.au for the most up to date details
This table is not indicative of the order of treatments, that is the responsibility of the beekeeper.
The colour code refers to the mode of action.

Product name Current 18/11/24	Bayvarol® PER95037	Apistan® PER95038	FormicPro® PER95344	Apivar PER94153	Apitraz PER94153	Apiguard® PER94655	Api-bioxal™ PER94609	Aluen CAP® Unregistered
Registration Status	Emergency use permit active Full Registration submitted	Emergency use permit active	Emergency use permit active Full registration progressing	Registered	Emergency use permit active Full Registration progressing	Registered 65570	Emergency Permit Active	Full Registration Application Submitted
Active ingredient	Flumethrin	Tau-fluvalinate	Formic acid	Amitraz	Amitraz	Thymol	Oxalic acid	Oxalic acid
Chemical Type	Synthetic pyrethroid	Synthetic pyrethroid	Organic acid	Synthetic formamidine	Synthetic formamidine	Organic extract	Organic acid	Organic acid
Product Type and dose for full size hive	plastic strips 4 strips per brood chamber	plastic strips 2 strips per brood chamber	gel strips 2 strips per brood chamber	plastic strips 2 strips per brood chamber	plastic strips 2 strips per brood chamber	gel product 50g per hive	Solution&Powder – 5mL per frame full of bees, max dose 50mL per hive, using syringe Powder – Vaporization 2.3g dose per hive	Cellulose strips 4 strips per brood chamber (pending full registration)
Temperature/ hive type limitations for treatment	Not critical	Not critical	Only treat when ambient daytime temps are between 10 °C & 29.5°C	Not critical	Not critical	Only treat when ambient daytime temps are between 15°C & 40°C	None	No
Treat with supers on hives	Yes - Comb honey cannot be collected or sold if treated when supers present	No	Yes	No	No	No	Yes	Yes (pending full registration)
Treatment time	6-8 weeks	6-8 weeks	7 days	6-10 weeks *no more than once per year	6 weeks *no more than once per year	2 weeks then additional tray for 4 weeks (Total of 6 weeks)	Minimum of 5 days between applications *Either method repeat only twice per year	42 days (pending full registration)
Can nuclei colonies be treated	Yes – (2 strips per nuc)	Yes – (1 strip per nuc)	Colonies need to be a minimum of 6 frames of bees	Yes - (1 strip per nuc)	Yes - (1 strip per nuc)	Yes (25g per nuc)	Yes 5mL per frame full of bees for solution trickling with caution	Yes - 2 strips per nuc (pending full registration)
Withholding period	Not required when used as directed.	Do not have supers or harvest honey when strips are in	Only harvest honey after 2 weeks from the end of treatment	0 days after removal of strips. Do not have supers on when strips are in	2 weeks from the end of treatment. Do not have supers on when strips are in	0 days	0 days , hive re-entry 48 hours after treatment	None (pending full registration)

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Broad spectrum “organic” chemicals

The chemicals covered here are oxalic acid (OA) and thymol. Formic is an organic acid which has already been discussed as a method of breaking mite reproduction. Oxalic acid is a readily available agricultural chemical, and thymol is a component of essential oil derived from the thyme plant. These “organic” controls (including formic) are amongst the most common methods of controlling *Varroa destructor* around the world. Their broad range of action means that the chance of mites building resistance to these chemicals is not impossible but extremely low (Animal and Plant Health Agency, 2024). Neither OA nor thymol will penetrate capped brood to interrupt mite reproduction.

> *"Organics are dumb chemicals for smart beekeepers.*
> *Synthetics are smart chemicals for dumb beekeepers."*
>
> Randy Oliver (pers.comm., 2023), who uses organic chemicals, splitting, drone trapping and mite resistant queens to control *varroa destructor* in his operation.

Oxalic acid is registered as Api-Bioxal with the APVMA under an emergency permit for use by dribble or sublimation. Aluen-CAP has a registration application submitted for the use of strips, also known as staples, which should be available for use late 2025. Oxalic acid is registered for use with honey supers on in Australia as it is already found in honey. Darker honeys will already have higher levels of OA. OA is non-lipophilic so will not contaminate beeswax. Thymol is registered as Apiguard gel. Thymol may accumulate in honey and is not registered for use with honey supers on as the flavour is too adversely affected to be useable. Ethereal oils such as thymol heavily contaminate beeswax initially but dissipate rapidly (Sánchez et al., 2021).

Table 8 lists the main concerns and advantages with these chemicals. Both these chemicals have inherent risks in handling and require protective equipment. At the time of writing lactic acid is the only other organic acid or essential oil seen as effective for mite control, but this has largely been superseded by OA. Both OA and thymol perform best if the hive has a brood break. There is ample information available online regarding their use, though be aware that context is critical to their efficacy. OA may cause brood damage (Stainton & Ponting, 2020).

Table 8. Advantages and disadvantages of various thymol and OA application methods.

Chemical method	Advantages	Disadvantages
Oxalic acid (OA)	All methods useable with honey supers on. 90-100% efficacy in broodless period	Damages open brood, both behaviour and longevity Does not penetrate brood caps May be less effective in tropics
OA Dribble (Api-Bioxal)	Quick and easy to apply on clustered bees.	Tropical bees do not cluster. Can still be used but best if broodless
OA Sublimation (Api-Bioxal)	Quick and easy to apply with the right equipment and face mask. No need to open hive	Wide variety of efficacy between application tools. Major safety concerns. Expensive equipment required Close hive ventilation off.
OA glycerine strips "staples" (Aluen CAP) Not yet approved	No clustered bees needed Safer than sublimation. 1:1 ratio more important than medium (Oliver, 2024)	May be not as effective in tropical climates. 1:1 acid: glycerine by weight (Oliver, 2024)
Natural sources rhubarb leaves etc	Grown at home.	Ineffective as there isn't enough OA present to kill mites
Thymol (Apiguard)	Wide temperature range 15-40˚C Can be highly effective even in hot climates, taking mite count of 70 down to zero (Oliver, 2024)	Honey supers must be off for six weeks total Damages open brood Does not penetrate brood Requires a brood break for best efficacy

Synthetic chemicals

> *"All beeswax foundation recently sampled from North America is uniformly contaminated with tau-fluvalinate, coumaphos and lower amounts of other pesticides and metabolites."* (Binnie, pers.comm., 2023)

The two main issues with use of synthetic chemical miticides are mites developing chemical resistance and chemical residues accumulating in honey and wax (Stainton, 2022). This is a major issue for beekeepers who rely on residue free beeswax for cottage industry cosmetics, candles, beeswax food wraps and propolis tinctures. For subtropical beekeepers, no synthetic miticide will penetrate capped brood. None allow for harvesting comb honey or using beeswax. Bayvarol is the only synthetic miticide approved for use with honey supers on in Australia, though honey harvested from the brood box must be maximum residue level (MRL) tested and no comb honey or wax is to be harvested. Bayvarol is not approved for use in other countries with supers on. Migratory beekeepers may be able to take hives to a colder area for a period long enough to remove supers and use synthetic miticide strips if needed.

Table 9. Miticides *Varroa destructor* has developed resistance to locally in different parts of the world (Source: Jack and Ellis, 2021). Miticide resistance has continued to spread.

Country	Noted resistance			
	Amitraz (formamidine)	Coumaphos (organophosphate)	Fluvalinate (pyrethroid)	Flumethrin (pyrethroid)
Western Hemisphere				
Argentina	X	X		
Canada		X	X	
Mexico	X		X	X
United States	X	X	X	
Uruguay				X
Europe and Eurasia				
Austria			X	
Belgium			X	
Cyprus			X	
Czech Republic	X		X	X
France	X		X	
Germany				X
Greece		X	X	
Ireland				X
Italy		X	X	
Poland			X	X
Slovenia			X	
Spain		X	X	
Switzerland			X	
United Kingdom			X	X
Near Eastern				
Israel			X	
East Asia and Pacific				
New Zealand	X	X	X	X

Each synthetic miticide has a very specific mode of action. Active ingredients are grouped by these different modes of action (Table 7). If the same mode of action is used repeatedly, even with different active ingredients, then a percentage of mites which happen to be unaffected by that specific mode of action will survive and gradually increase in numbers. This has often happened very quickly on regional scale as beekeepers see how effective and easy to apply synthetic miticide strips are. Most synthetic miticides are 99.5% effective with no mite resistance present. Beekeepers who fail to monitor mite numbers post treatment can be caught out and lose large numbers of hives. These chemicals have been accused of breeding weaker bees and stronger mites over decades in the USA, which compounds viral load issues discussed previously. Synthetic chemical use is now minimal throughout Europe due to awareness of these issues. Beekeepers primarily use organic acids and are now turning to new biotechnical methods and mite resistance breeding programs in large numbers. This is in stark contrast to the USA, where the 24/25 season brought catastrophic average hive losses of 62% partly driven by high virus levels and Amitraz resistance (US Department of Agriculture, 2025). Extensive information on how to use ‘organic’ and synthetic chemical miticides approved for use by Australian beekeepers can be found in the NSW DPI Varroa Management Tool (Appendix 1).

Using a Pettis Test or field bioassay to detect miticide resistance in mites

The most accurate method to determine if mites are resistant to a particular miticide is to alcohol wash a number of hives before and after treatment. Check whether the product is within used by date and has been stored correctly first. If the treatment is not effective when used as per instructions mites may be resistant to chemicals of that mode of action. A Pettis Test or field bioassay can provide a field determination on whether the product will be effective provided hive mite load is 5 or more per 300 bee alcohol wash (British Columbia Ministry of Agriculture, 2015):

1. Hang a 1x2.5cm (centimetre) piece of miticide strip in an alcohol wash jar
2. Add ¼ cup of bees collected from the brood area (Figure 25)
3. If possible leave jars in a dark warm room, incubator or even an esky kept at 34˚C with hot water bottles. Avoid low temperatures.
4. Count mite fall after 6 hours and remove fallen mites (killed by miticide)
5. Alcohol wash the bees and count mites collected (not killed by miticide)
6. Below 50% mite mortality by miticide after 6 hours may indicate resistance

The results of this test will vary with ambient temperature, mite infestation levels, miticide exposure times and sampling methods. Read the links provided in Appendix 1 for more details on the limitations of the Pettis Test prior to use.

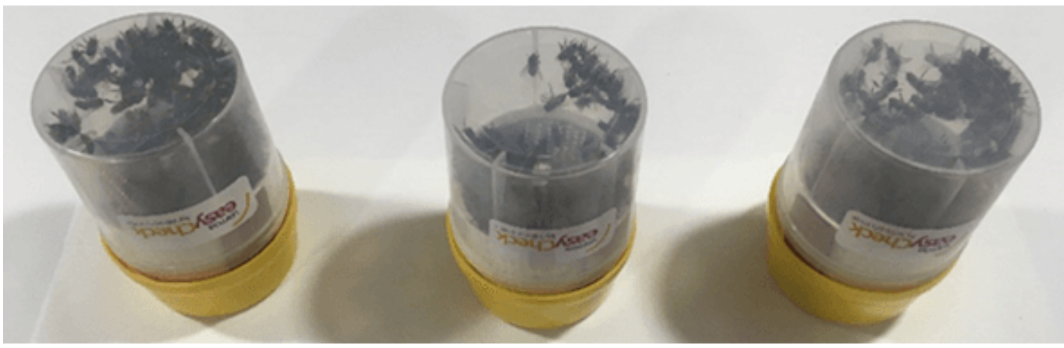

Figure 25. A Pettis Test by Véto-pharma using Varroa Easy Check jars (Marsky, 2023)

Part III: Planning for the future

The invasion phase

High up in an old bloodwood tree in dense bush just west of Grafton a feral hive is on alert. A few weeks ago foragers robbed out a dying hive and brought home free stores. Now bees are emerging from brood unwell. The hive feels off. It doesn't know why. Instinct kicks in and the hive collectively absconds to find a new home. The abandoned hollow is quickly robbed out by another hive, unaware of the small red disc chemically masking itself as it climbs aboard a forager for a free ride. As the foragers fly away with their deadly cargo small black hive beetles buzz past to feast on the last of the old pollen and brood in the hollow.

Multiply this by up to 150 hives per square kilometre. Now add 394,112 managed hives in NSW alone. For some "managed" is a strong word. Every one of these hives is a potential naïve and unexpecting breeding incubator for Varroa. Followed by a wave of SHB quick to take advantage of a weakened hive. This is the reality for Australian beekeepers. This invasion could take five to ten years before feral hive numbers and beekeepers who cannot regulate mite numbers stabilise to a new lower density. There are large unknowns in an Australian climate with or without Deformed Wing Virus. The certainty is for a very high reinfestation rate. The local Varroa Development Officer is a great contact point to discuss current local risks and successfully utilised strategies.

Varroa Development Officer comments on the Varroa invasion wave spreading outwards from the NSW central coast (Taylor-Brown and Fairhall, pers.comm., 2025):

- Hundreds of mites may be found in a mite wash with the hive apparently unaffected. 40 mites per wash is a more common hive health tipping point.
- Organic chemical treatments do not perform best under high stress, high mite load conditions. These treatments are harder on bees and less consistent in results. Brood manipulation methods are untested in these conditions but may come with the same warning against causing stress to a weakened hive.
- As seen in other countries, recreational beekeepers are being hardest hit with invasion phase hive losses. They may have a reluctance to use higher efficacy synthetic chemicals, less experience, less resources and different goals leading them to different management decisions.
- Hives may reach treatment thresholds again within two to six weeks of the previous treatment finishing, if the hive can be brought below threshold at all
- SHB is a major and final threat to a hive weakened by Varroa
- One year on from initial invasion beekeepers are starting to see a longer break between treatments, meaning the peak of the invasion has past
- Some migratory beekeepers have been able to move hives from ahead of the invasion wave to behind it, avoiding the worst reinvasion numbers
- Beekeepers west of the Great Dividing Range are suffering notably lower reinvasion numbers due to lower numbers of feral hives
- Around 90% of observed feral hives have died off in 6-18 months. This is far quicker than observed in other countries during the invasion phase.
- Beekeepers choosing not to control mites are losing 90-100% of their hives in 6-18 months (same loss rate as feral hives)

Planning your year with integrated methods

Once Varroa numbers stabilise and the initial invasion is past beekeepers can gradually cut back on control methods. Regardless of whether DWV appears in European bees in Australia, the monitoring threshold for action will likely drop as viral loads inevitably rise. The treatment threshold in the USA is now down to 1-2%. For much of the northern hemisphere, treatment cycles are straightforward. Honey is harvested a few times per year and Varroa control is organised around predictable seasons. This is in stark contrast to Australia, where tropical beekeepers may leave supers on all year and simply harvest when full to take advantage of often unpredictable flowering events throughout the year. This highlights the importance of starting at the top of the IPM Broodcomb and working down. Hives need the best Varroa resistant genetics the beekeeper can find or create, teamed with the best hive husbandry practices. Beekeepers will need to know and understand their chosen monitoring and Varroa control methods to build a new beekeeping calendar. Figures 26 and 27 below are from USA sources with winter brood breaks and little consideration of biotechnical brood manipulation methods.

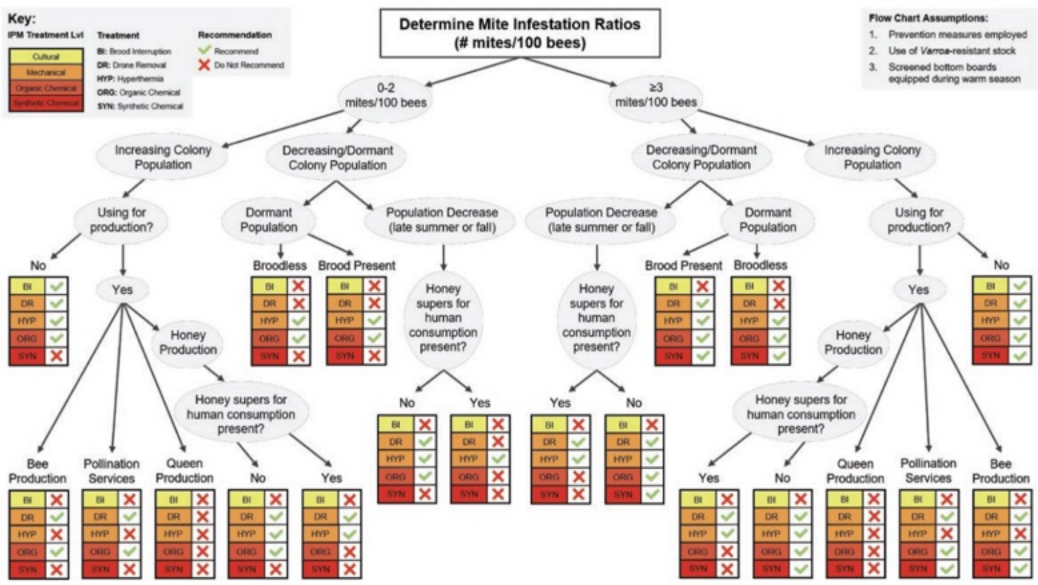

Figure 26. Treatment decision chart from Jack and Ellis (Source: University of Florida, USA. (2021)

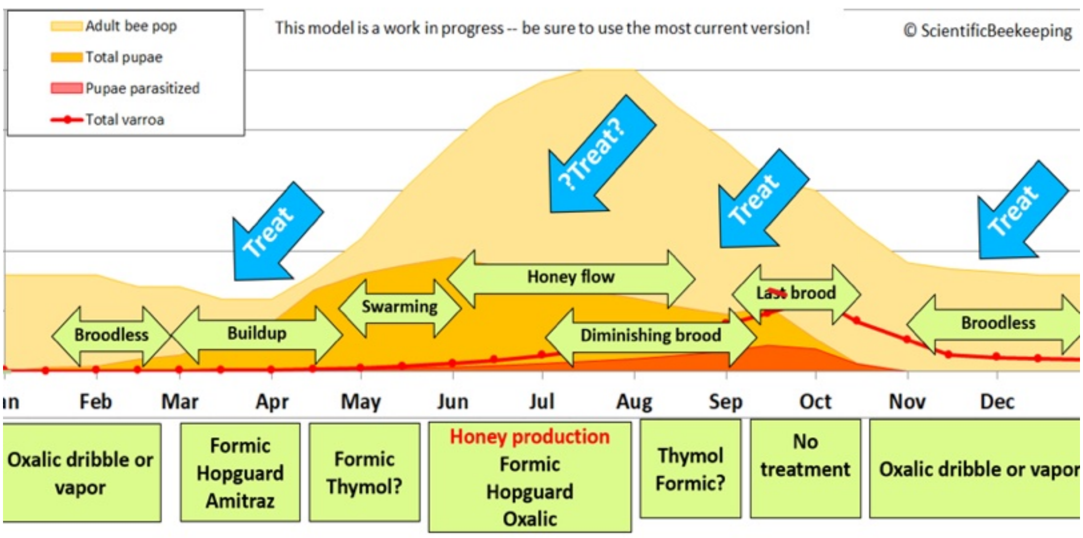

Figure 27. Appropriate treatments for the time of season by Randy Oliver (Source: 2025).

To assist in making an annual plan:

- Work through the IPM Broodcomb regularly as new options and better varroa resistant queens become available
- Monitor regularly so you know when the invasion phase is past, when your plan needs to change and which of your queens are controlling mites best. Some years will be worse than others. When the bees are doing well, the mites are doing well.
- Make a graph of temperature, worker brood, drone brood, nectar flows and mite numbers for your specific local area so you can match your chosen methods with the most effective time of year
- Randy Oliver (2025) has an interactive mite population model at https://scientificbeekeeping.com/randys-varroa-model/ . This can be used to estimate how many mite control points are needed and when in the year depending on how effective each mite control method is (Figures 28-30). Note this will likely not be enough mite control for the invasion phase.
- Once the invasion phase is past two to four Varroa control points per year may be required in the subtropics if using high efficacy methods such as isolator cages or synthetic miticides, for example early spring, summer, autumn and winter (B the net (1), 2023)
- Brood breaks and trap cages should be timed for gaps in nectar flows or when brood manipulation is required, such as to prevent swarming. The queen isolator could also be used to maximise the honey flow.
- One month of drone trapping may control mites for two months (Taylor and Goodwin, 2021). Best used in Spring and summer.
- For tropical beekeepers formic acid is best scheduled for colder times of year
- Oxalic acid is best used with a brood break
- Bayvarol is the only synthetic chemical which can be used with supers on but beeswax cannot be used for cut comb. Honey harvested from the brood box must be tested for miticide residue prior to use.
- Have your chosen equipment prepared well in advance and know when you are expecting to use it, even if plans change
- Team up with neighbouring beekeepers for the most effective mite control and queen breeding efforts

Table 10 compares the cost of three different mite control systems over three years. A brood break and phoretic mite cut down could be provided using a home made single frame isolator, a two frame isolator, vertical queen excluders (block the queen travelling between sections via the entrance) or a small queen cage of any type followed by oxalic acid vaporizing or removing the first two frames of capped brood. Oxalic acid and glycerine staples are not available in Australia at the time of writing but are provided as a common comparison with 45% efficacy (Oliver, 2025). Aluen Cap is the commercially made version expected to be available late 2025 through Lyson Australia. Aluen Cap is listed as effective as synthetic miticides without leaving residues in beeswax or honey. Testing in southern USA, a similar climate to subtropical Australia, showed Aluen Cap at around 65% efficacy and maintaining low varroa numbers rather than consistently providing a complete knock down like a synthetic miticide (Binnie, 2022). Some beekeepers will use synthetic miticides in the invasion phase only then swap all frames out for fresh beeswax once mite numbers stabilise.

Table 10. Per hive cost comparison of three different mite control systems. All three methods successfully control mite numbers in a subtropical environment under high reinvasion conditions with brood and supers year round when run through Randy Oliver's Varroa Model (Figures 28-30). None of these plans are likely to be sufficient during the initial invasion phase. These plans may not adhere to state requirements. OA staples are not available in Australia at the time of writing but are included as a common mite control comparison. Bayvarol and Formic Pro price ranges used are from Lockwood Beekeeping Supplies 2025 catalogue small pack to bulk buy. Prices for two frame isolators are from Lyson Australia down to cheaper online versions.

Plan	**Chemical free (Figure 28)**	**Organic acids (Figure 29)**	**Synthetic strips (Figure 30)**
Method (used each year) **$ per hive per year**	3x two frame queen isolator **$50-$85/hive initial purchase only**	2x Formic Pro $9.33-$18.75/hive 3x OA staples $7.15/hive **$40.11-$58.95/hive**	2x Bayvarol $8.98-$12.90/hive 3x Formic Pro $9.33-$18.75/hive **$45.95-$82.05/hive**
Times in hive ($10 labour per hive visit)	9 per year = $90 (3x per year find queen = $30)	10 per year = $100	10 per year = $100
Total cost/ hive/ year	**$170-$205 initial, Future years $120/hive/year**	**$140.11-$158.95 /hive/year**	**$145.95-$182.05 /hive/year**
Advantage	No chemical use Can boost honey flow	No residual chemicals No queen finding	No queen finding
Disadvantage	Finding queens Temporary reduced numbers	Making staples (labour, equipment not included)	Contaminated beeswax

Randy Oliver's Varroa Model
https://scientificbeekeeping.com/randys-varroa-model/

This is a great tool to assist Australian beekeepers in planning Integrated Varroa Management throughout the year. Be aware that invasion phase mite numbers are far higher. The closest available settings on the model for Australian users are used to calculate Figures 28-30:

- "X" (southern hemisphere, right hand side of the yellow bar)
- Colony type "a" (dry subtropical with no brood break, left of yellow bar)
- Mite immigration level 4 (treatment free urban neighbourhood)

The model shows the potential to successfully control mite numbers throughout the year with three mite control points. This could be three brood breaks WITH a minimum of 85% of total mites removed using a two frame queen isolator cage (Figure 28) or queen caging with an oxalic acid dribble or sublimation treatment. The possible combinations of mite control methods is infinite, so each beekeeper needs to investigate their own chosen methods. Note that if any of the three control methods shown falls by 5% efficacy mite numbers begin climbing with no return to baseline. The model can be customised for increased levels of mite resistance in queens. Scroll to the far right tab to use the "Brood Break" feature and add the percentage of mites removed if needed. As an example, isolator cages are designed to remove phoretic mites as well as varroa in brood. Oxalic acid vaporizing after caging the queen would have a similar effect.

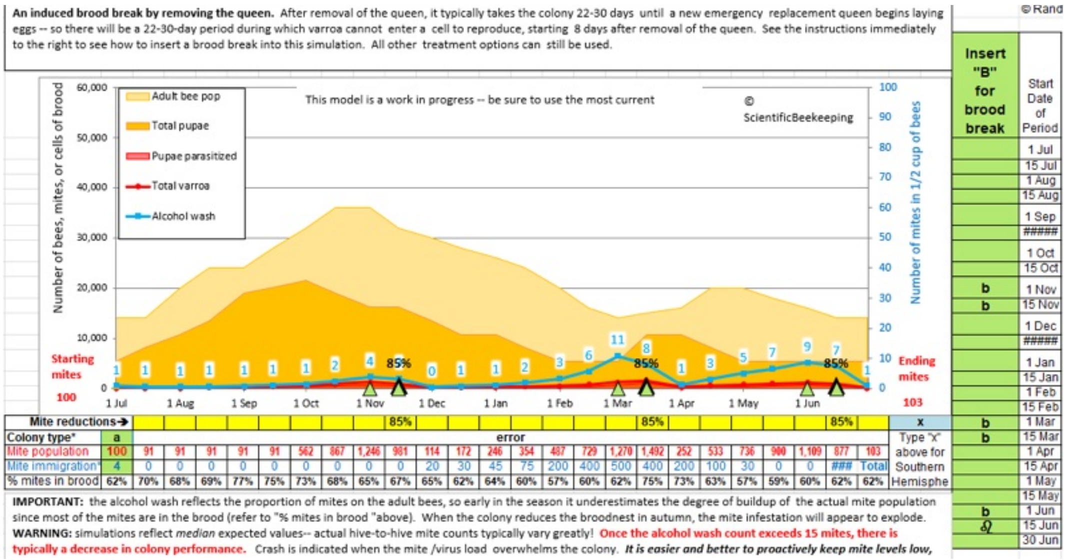

Figure 28. Randy's Varroa Model on the "Brood Break" tab showing three uses of the two frame queen isolator with a conservative estimate of 85% mite removal.

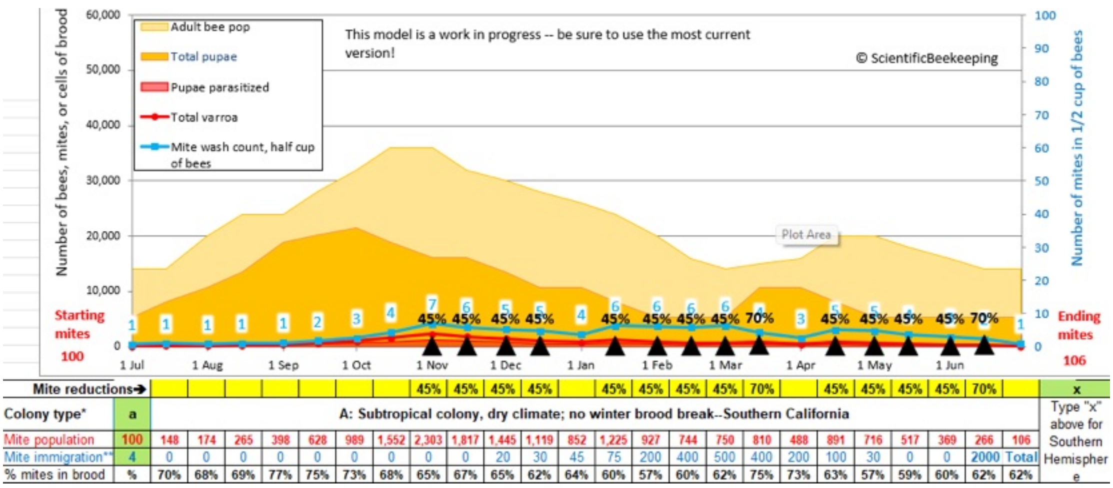

Figure 29. Randy's Varroa Model on the "Current version" tab showing two Formic Pro treatments and three extended release oxalic acid and glycerin sponge treatments (not yet approved for use in Australia). Note Formic Pro can have highly variable efficacy, is temperature dependent and can be hard on queens.

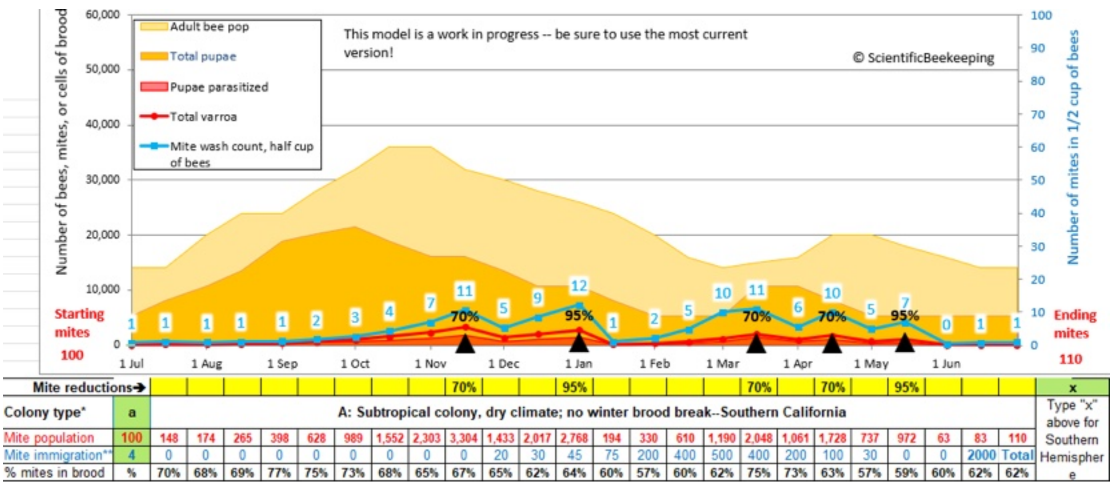

Figure 30. Randy's Varroa Model on the "Current version" tab showing three Formic Pro and two Bayvarol treatments. At the time of writing this is the only varroa control system possible for a beekeeper with supers on all year who chooses to only use commercially made treatment strips. Risks include Formic Pro issues and Varroa building resistance to Bayvarol.

The future of our industry

USA Beekeepers have recorded unsustainable average annual losses of 62% of hives for the 2024-2025 season. This is the highest loss rate since colony loss rates were first recorded in the 2010-11 season. This has been driven by large commercial operation losses (Giacobino, 2024). The reasons for this are complicated, but the primary reason noted for hive death is generally *Varroa destructor*. Major loss drivers are viruses, parasites, pesticides (within and outside the hive), synthetic miticide resistance, habitat loss, climate change (natural disasters) and disease. This contrasts with European and New Zealand loss rates of 16% and 13% respectively. The Varroa Resistenz 2033 Project in Europe is working to transition beekeepers towards varroa resistant queens through biotechnical control methods.

Varroa could be providing Australian beekeepers with a window into a potential future they do not want a part in. *Apis mellifera* has been suggested as a marker for agricultural chemicals in the environment. Bees bring these chemicals back with hive resources, where they accumulate in beeswax. Beekeepers then treat Varroa with synthetic chemicals which also accumulate and interact. Melted down frames are then reprocessed into foundation and reused, a process which often fails to remove chemical residues. 1,900 Cuban beekeepers using only their collective queen breeding efforts to manage Varroa after a 5-8 year transition drive could present an attractive picture for Australian pollination suppliers facing the cost, labour and environmental interactions of synthetic miticides.

When Australian beekeepers make decisions and plans for how to manage Varroa, it is imperative that the sustainability of the industry is considered. Beekeeper goals need to include a view of what the industry will look like for future generations of beekeepers. This includes the ability to keep healthy bees as well as market quality, residue free hive products. The average age of an Australian commercial beekeeper is 54 years, so this is not a far off future consideration for the industry. The conclusions and recommendations below are drawn with intergenerational goals in mind.

Conclusions

Integrating *Varroa destructor* into Australian beekeeping will require a dedicated shift in mindset and a willingness by beekeepers to alter the way they keep bees. Survival will require beekeepers to walk a fine line between casting assumptions aside and critically analysing how potential solutions fit the Australian context. Successful beekeepers will be clear on their goals and continually reassess their strategy. Once the invasion phase has past it will be important to consider sustainability of the industry for future generations of beekeepers.

An integrated approach will see beekeepers breeding or using the most mite resistant queens available, maximising their hive husbandry methods for hive health and mite resistance, monitoring frequently for threshold limits, using biotechnical methods to interrupt mite reproduction, and using chemical controls responsibly if required to meet goals. Excluding Varroa for so many decades with world class biosecurity practices is now reaping benefits for Australia. Beekeeping industries around the world successfully operate while managing Varroa. This has provided Australian beekeepers with extensive research and practical learnings from a range of climates. The ability of the Australian beekeeping industry to adapt and thrive in the world's most variable farming climate shows that Australian beekeepers are up to the task.

Recommendations

There are a range of actions which could be taken to improve the ability of the Australian beekeeping industry to manage Varroa mite. Many are already underway. Australia's National Honey Bee Breeding Strategy 2024-2029 will bring Varroa resistance into line with the constant selection for productive, healthy and docile queens (Oldroyd and Barron, 2024). Funding for this is critical due to the economic difficulties of breeding Varroa resistant queens already discussed. Australia's *Varroa destructor* Research Strategy 2024-2027 is committed to developing a unique approach to Varroa control tailored to the Australian industry (Oldroyd et al., 2024). Intense monitoring and testing for DWV continues. Trials and research world wide continue the search for an efficient and accurate way to monitor for mites. Recommended actions which may not have been addressed by industry include:

- Nuffield Scholarship or similar funding to survey biotechnical methods used in Europe and Asia, particularly those that may be adapted for large scale Australian commercial beekeepers with brood year round.
- Extensive trials and research into biotechnical methods with Australian bees, with follow up education extension for Australian beekeepers. This should include various methods and application timing. This will address the volume of misinformation around biotechnical methods in Australia. Biotechnical methods will be critical if or when tropi mite arrives in Australia.
- Expand and produce this Nuffield report as an information booklet for beekeepers seeking more information on biotechnical methods.
- Funding for improved marketing strategy training for Australian honey producers. *Varroa destructor* will inflict 30% extra production costs upon Australian beekeepers. With Indian honey sitting beside Australian honey on the supermarket shelf for a significantly lower price there is little scope to recoup this cost without improved marketing strategies beyond the knowledge of the average Australian beekeeper.
- Increased lobbying of the APVMA for the use of Aluen Cap™ oxalic acid strips by Australian beekeepers as soon as possible. This needs to be followed by extensive testing to determine the true mite control efficacy and health effects for tropical Australian bees and their hive products under wet, humid conditions.

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See Appendix 1: Recommended reading and viewing for a list of great reference books, articles and websites.

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Appendix 1: Recommended reading and viewing

Pests and diseases

Brood depilation; removing cell caps with a wax strip to find Tropi mite or search for recapping behaviour https://www.youtube.com/watch?v=_EDaf6GQXJI&t=37s

Tropi mite information https://www.youtube.com/playlist?list=PLTO0ebla1CxLRNqwx9O8Hr3fsS0VQ-1aY

NSW DPI Prime Fact 764: Small hive beetle management options https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/220240/small-hive-beetle-management-options.pdf

Biosecurity Manual for Beekeepers (2016) https://beeaware.org.au/wp-content/uploads/2019/05/Biosecurity-Manual-for-Beekeepers.pdf

Varroa resistant queens

Australian Native Bee Association https://australiannativebee.org.au/ .

Mondet, F. (2025, February 6). *Honey bee resistance is a function of odors coming from the brood*. Sustainable beekeepers guild of Michigan. Michigan, USA. https://sbgmi.org/membership-meeting-video (pay $20 membership to view all resources)

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Riley S. (2024, December 28). *The honeybee solution to Varroa*. The National Honey Show. Surry: United Kingdom. https://www.youtube.com/watch?v=dcJO19QHAKE

Varroa resistance information in the UK https://www.varroaresistant.uk/

Extension Aus Professional Beekeepers; information on Australian research https://extensionaus.com.au/professionalbeekeepers/home

Randy Oliver; interactive mite control spreadsheet, breeding Varroa resistance and extensive testing on organic chemical controls www.scientificbeekeeping.com

Harbo Assay https://www.harbobeeco.com/measure-vsh/

Pin pricked brood https://tavistock-beekeepers.org.uk/wp-content/uploads/2021/03/Protocol-for-VSH-Colony-Selection.pdf

Freeze dried brood https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/535604/Testing-for-hygienic-behaviour.pdf

UBeeO https://opterabees.com/

VSP https://sbgmi.org/ (pay $20 membership to access all information)

Cuban bees

www.apiservices.biz/documents/articles-en/cuban_bees_selection_varroa_resistance.pdf

Luis A.R., Grindrod I., Webb G., Piñeiro A.P., Martin S.J. (2022). Recapping and mite removal behaviour in Cuba: home to the world's largest population of Varroa-resistant European honeybees. *Nature* **12**, 1-9.

Hive husbandry

Borba R. (2015, September 27). *The propolis envelope and honeybee health*. Heartland Apicultural Society. Michigan, USA. Retrieved from https://www.youtube.com/watch?v=MefRdj5vR6Y

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Schiffer T. (2021). The true price of honey. *Natural Bee Husbandry* **20**.

Heath D. (2021). *Treatment-free beekeeping*. West Yorkshire: Northern Bee Books.

Seely T.D. (2019). *The lives of bees*. Princeton: Princeton University Press.

Mite threshold monitoring

Alcohol wash https://www.youtube.com/watch?v=MgMMetfQ9J0

Mite drop on a baseboard https://www.youtube.com/watch?v=90qgGnHLigw
Apizoom app https://www.apizoom.app/

Soap wash https://www.youtube.com/watch?v=Xc_1IfGg0uw

Sugar shake https://www.youtube.com/watch?v=MgMMetfQ9J0

Drone uncapping https://www.youtube.com/watch?v=3bSgyUSj-CQ

Carbon dioxide https://www.youtube.com/watch?v=NZQDbgWcBbE

BeeScanning varroa finding app https://www.beescanning.com/

Randy Oliver; Varroa model https://scientificbeekeeping.com/randys-varroa-model/

Breaking Varroa reproductive cycle

Uzunov A., Gabel M., Büchler R. (2023). Summer brood interruption for vital honey bee colonies. West Sussex: Apoidea Press.

Varroa Controller Australia https://www.varroacontrolleraustralia.com.au/

How to apply FormicPro® strips https://www.youtube.com/watch?v=FDtdRtysDAo

FormicPro® makers website https://nodglobal.com/

Removing phoretic mites

Oliver R. (2016). Powdered sugar dusting – sweet and safe, but does it really work? Part 3. Retrieved from https://scientificbeekeeping.com/powdered-sugar-dusting-sweet-and-safe-but-does-it-really-work-part-3/

Jack C.J. and Ellis J.D. (2021). Integrated Pest Management Control of *Varroa destructor* (Acari: Varroidae), the most damaging pest of (*Apis mellifera* L. (Hymenoptera: Apidae)) colonies. *Journal of Insect Science* **21(5),** 1-32.

Chemical management options in Australia https://www.dpi.nsw.gov.au/animals-and-livestock/bees

Field Bioassay to detect varroa mite resistance in the apiary
https://www.blog-veto-pharma.com/en/field-bioassay-to-detect-varroa-mite-resistance-in-the-apiary/
Pettis Test - Detecting Varroa Mite Resistance to Apistan, Apivar & Coumaphos
https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/animal-production/bee-assets/api_fs223.pdf

Appendix 2: Chemical free trial results

Method

55 hives on 6 stationary apiary sites near Ballina NSW had mite infestations counted monthly using an alcohol wash of approximately 300 bees. Hives are timber with 9 frames of brood and 1-2 super boxes of honey. Varroa first arrived in each apiary at different times between February and June 2025.

Integrated Pest Management of Varroa followed the IPM Broodcomb developed by Ballina Honey. Hives were requeened in May 2024 using queens from Australia's fledgeling Varroa resistant breeding program run by the Australian Queen Bee Breeder's Association (AQBBA). *Dalotia coriaria* beetle were released into each apiary to control Small Hive Beetle pupae in the soil around hives. Drone brood removal was undertaken on all hives whenever the provided drone frame was capped off.

Varroa reproduction was interrupted and phoretic mites trapped out using a two frame queen isolator purchased from Lyson Australia. In late summer and autumn an empty frame of worker brood and an empty frame for building out drone comb were used in the isolator, which was installed when a 3% mite threshold was reached. Two worker brood frames were used in the isolator over winter, installed at a 0.3% mite threshold.

Result

This trial is ongoing. Hive health and production have been severely impacted by record wet weather throughout the trial period. Mite numbers have been extremely variable within and between apiaries due to the initial invasion (figure 31). There has been a loss of 16.36% of hives, with 12.73% of this loss at Apiary 1. This has included 0% deaths directly from varroa, with 12.73% absconded (bees left hive) and 3.64% death by Small Hive Beetle slime out (both at Apiary 1). 47.27% of hives superceded (replaced) their original queen (figure 30). Average mite count when installing isolators was 6.89% and when releasing the queen 11.27%. 10.91% of hives had too few bees in the hive to alcohol wash when releasing the queen, 7.27% at Apiary 1 and 3.64% at Apiary 2.

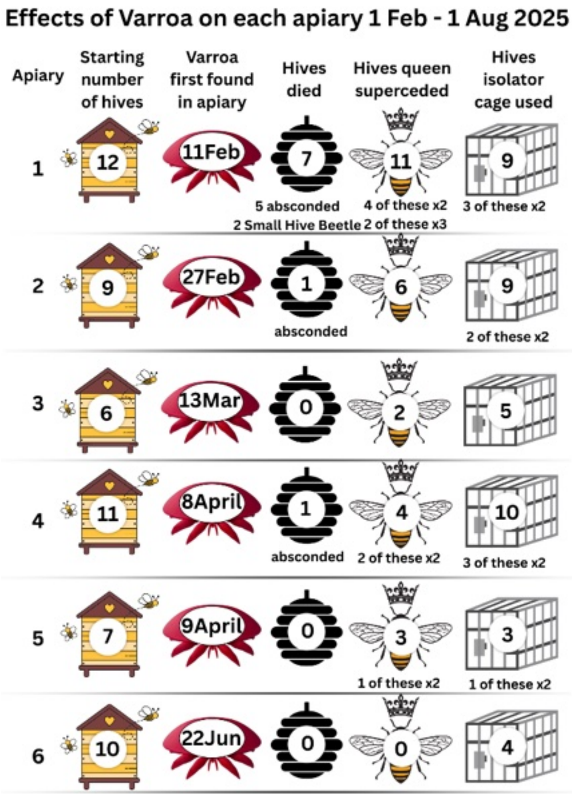

Figure 31. Effects of *Varroa destructor* on each apiary 1 February – 1 August 2025.

Conclusion

The two frame queen isolator cage method has proven convenient to use in this trial, but is struggling to keep mite numbers down under the very high reinvasion numbers seen in the initial varroa invasion phase. Higher than average rainfall and number of rain days has potentially caused more issues for the hives in the trial than varroa. However, the late arrival of varroa at Apiary 6 shows that hive death and supercedure issues can be attributed to varroa mite. Small Hive Beetle pressures have been less than expected compared to other local beekeepers. Local beekeepers were not overwhelmingly inclined to try these methods due to a reluctance to find and handle the queen as well as concerns around cutting back brood numbers.

Full trial starting October 2025

From October 2025 200 hives across 10 stationary apiaries will be used to trial chemical free biotechnical and low chemical use varroa control methods. All hives will be requeened using queens from the AQBBA varroa resistant queen breeding program. Drone brood removal will be used in all hives using a drone frame uncapped every 24 days. *Dalotia coriaria* beetle will be released into each apiary to control Small Hive Beetle. Oxalic Acid sponges will be used to assist in keeping mite numbers below threshold. When hives reach a threshold of 3% in a monthly alcohol wash two vertical queen excluders will be used to separate the brood into three sections without finding the queen. The same sequence as above will be used using only the section holding the queen (determined by the presence of eggs after 11 days).

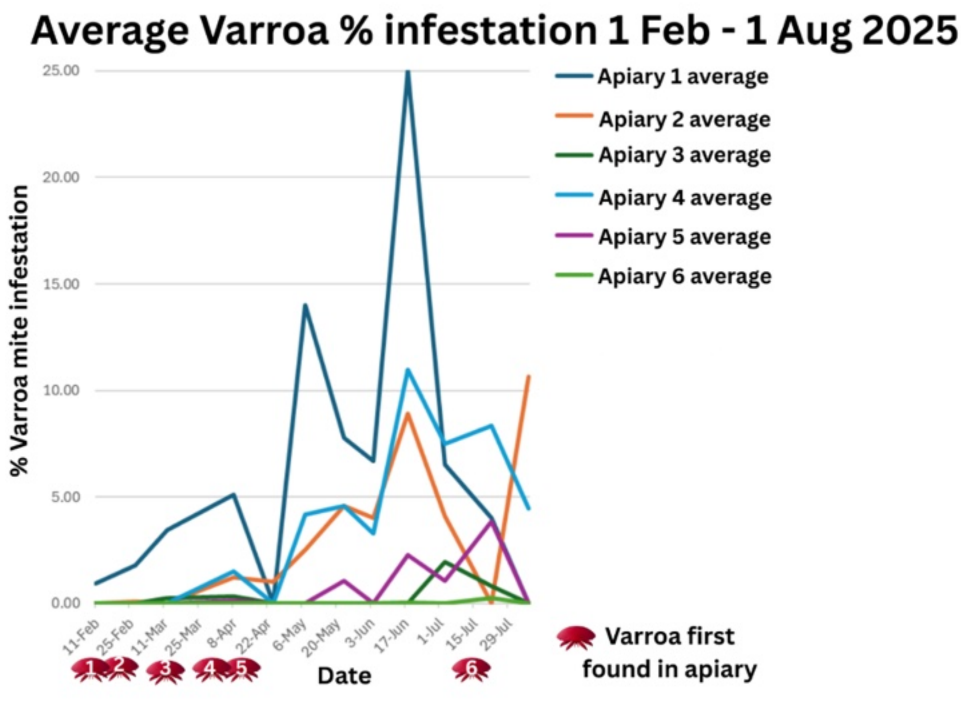

Figure 31. Average percentage infestation of *Varroa destructor* at each apiary between 1 February and 1 August as determined by a monthly alcohol wash of approximately 300 bees.