Plant Health AUSTRALIA

Varroa Mite Preparedness of Pollination Dependent Industries

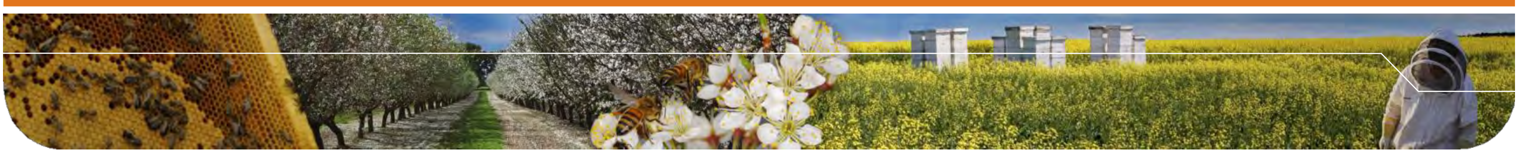
Prepared by Plant Health Australia

December 2013

HAL Horticulture Australia

Australian Government Rural Industries Research and Development Corporation

RIRDC



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Executive Summary

For every year Australia remains free of Varroa mite, industries which rely on honey bee pollination together receive a benefit of $50.5 million per year. Pollination dependent industries represent over 65% of all the horticultural and agricultural crops produced in Australia. These industries require bees for pollination as they are either self-incompatible or only achieve a commercially adequate yield through honey bee pollination. The data collected from the pollination census conducted for this report clearly shows the dependence of industries on honey bees as pollinators. This makes pollination dependent industries incredibly vulnerable to honey bee pests and diseases and in particular, Varroa mite which is known to decimate wild honey bee colonies and severely impact managed hives.

The impending threat of Varroa mite on the livelihoods of pollination dependent industries and beekeepers themselves is severe and will impact on the production of horticulture in Australia. Pollination dependent industries and beekeepers need to work together to mitigate the risk of Varroa mite entering the country and develop both short and long term contingency plans to maintain effective pollination in the event of Varroa mite establishment.

Pollination dependent crop industries need to address the current gap in R&D work into alternative pollination techniques and selective breeding of crops to minimise reliance on pollination vectors. In the event of an incursion, emergency response procedures would create quarantine borders which may restrict hive movement at a regional or state level. The location and availability of hives from year to year is not consistent or guaranteed as shown in previously published reports. Although seasonal hive movements, outside of pollination services, are dictated by unpredictable floral resource availability, there is still an over-reliance by industries for basic decisions on past seasons hive availability. This variable hive availability also does not take into account the future possibility of these services not being available due to quarantine restrictions.

This report highlights individual industries dependence on honey bee pollination and evaluates the effect a Varroa mite incursion may have on short-term and long-term pollination services. The report provides eight recommendations that could be employed to mitigate the effect of a Varroa mite incursion and improve pollination dependent industries′ overall preparedness.

Introduction

Managed honey bees[1] are found Australia-wide with approximately 673,000 registered hives in Australia managed by 10,500 beekeepers (Plant Health Australia 2012a). The Australian honey bee industry produces between 20,000-30,000 tonnes of honey annually making Australia the ninth largest producer of honey in the world, exporting about a third to over 38 countries (Kneebone 2010). The Australian honey bee industry has an overall estimated gross value of production of $90 million a year which includes the production of honey, beeswax, queen bees and paid pollination services (RIRDC 2012). However this figure severely understates the importance of honey bees to the agricultural industry as a whole.

The worlds agricultural industries are based on the production of agricultural produce from the reproduction of plants which in most cases relies on the fertilisation of an ovule by pollen known as the act of pollination (RIRDC 2010). The complexities of crop pollination vary from:

1. Self-pollination: where a flower produces pollen and fertilises itself or other flowers on the same plant. Some self-fertile plants may still need an vector to move pollen from the anthers to the stigma (RIRDC 2010).
2. Self-incompatible or self-infertile: where the plant has a mechanism that prevents self-pollination and requires the use of vectors for the transfer of pollen. Examples of self-incompatibility are when male and female flowers are on different parts of the plant, on a different plant entirely or when female and male flowers occur at different times on the same plant (Goodwin 2012).

Pollination by insect vectors is essential to fruit production and can account for up to 50% increases in fruit set (Abrol 1993). Bee pollination comes from sources such as wild honey bees[2], commercially reared honey bees and native bees[3] (Cunningham et al. 2002). Over 65% of horticultural and agricultural crops introduced to Australia since European settlement require bees for pollination (Gordon and Davis 2003) as they are either self-incompatible or only achieve a commercially adequate yield through pollination vectors (RIRDC 2009a). Honey bees forage for nectar and pollen for food and as a direct result of their activities pollinate plants resulting in increased seed or fruit set, improved storage qualities and shape of some fruit, and a more even maturation of some crops (Plant Health Australia 2013a). In temperate-zone agriculture and horticulture it is widely assumed that all pollination by animal vectors is done by honey bees with contributions made from other fauna only minimally recorded (Cunningham et al. 2002). The pollination market in Australia currently involves 481 commercial pollination businesses supplying 220,000 hives (Commonwealth of Australia 2011) across Australia.

In Australia, significant pollination of crops occurs from the large population of wild honey bees that are found throughout Australia. This means that pollination of crops often occurs without any deliberate intervention from, and at no cost to, the grower. This incidental pollination means the level of awareness about the importance of pollination by bees for pollination dependent crops is lower than might be expected given its importance (RIRDC 2010). Studies have shown that the transfer of pollen by honey bees can increase yields in some crops by 150% (Mcgregor and Bean 2009) in comparison to the yield obtained without the use of pollination vectors.

[1] Honey bees in this report refer to European honey bees (*Apis mellifera*)

[2] Wild honey bees in this report refers to European honey bees that are not managed by a beekeeper and live wild in the environment

[3] Native bees in this report refers to bee species found naturally in Australia, not of the *Apis* genera

Australia's relative freedom from many of the debilitating pests and diseases that affect honey bees in other countries has allowed for plant producers to become reliant on incidental pollination or only require minimal use of commercial pollination companies. Australia's climate and geography provides an ideal environment for honey bees as the native floral nectar resources available (such as Eucalypts) produce large quantities of nectar and pollen. As a consequence, Australia has a large population of wild honey bees that provide significant free pollination services to Australian agriculture and horticulture.

However Australia's biosecurity is constantly threatened from increased trade, travel and changes in the environment which increase the chances of a honey bee pest or disease entering the country. One of the biggest threats to the Australian honey bee industry is the Varroa mite (*Varroa destructor*[4]) which over the last 50 years has spread to every major beekeeping area in the world except Australia, making it the most serious pest ever of the honey bee (Anderson 2006). Varroa mites are an external parasite that feed on the haemolymph of drone, workers, larvae, pupae and adult bees (Plant Health Australia 2012b). The Varroa mite weakens bees, shortens their lives, or causes death from virus infections that otherwise would cause little harm. Unless urgent action is taken, infested colonies will slowly decline until all honey bees are dead (RIRDC 2010).

The effect of Varroa mite in other countries has seen wild honey bee colonies and managed colonies drastically decline (Cunningham et al. 2002). In the US and Europe, Varroa mite killed 95-100% of unmanaged or wild honey bees within three to four years of infestation (Commonwealth of Australia 2011). While efforts are being made to prevent an incursion into Australia, it is generally accepted that Varroa mite will eventually become established in Australia (RIRDC 2010). Varroa mite is expected to progressively kill 95-100% of Australia's wild honey bee population, greatly reducing the free pollination service they provide. The effect on commercial beekeepers will be the costs associated with implementing control measures, increased labour requirements, and the need to replace infected colonies (RIRDC 2010). The effect on pollination dependent industries will be the loss of incidental pollination and increases in the direct costs of pollination services and/or the possibility of insufficient number of hives being available (Gordon and Davis 2003).

[4] Another closely related exotic species of Varroa mite is *Varroa jacobsoni* which is often discussed together with *Varroa destructor.* However this report only focuses on *Varroa destructor* K and J haplotype

Project background and method

In 2009, Plant Health Australia (PHA) and the Australian Government Department of Agriculture conducted a survey of beekeepers throughout Australia to determine the movement of commercial hives and the type of crops pollinated through their services. The results of the survey were summarised into the report "Collection of data and information about pollination dependent agricultural industries and the pollination providers" (herein 2009 pollination report). The overall findings of this report indicated that the routine long distances that hives are transported mean that rapid detection of incursions are critical in order to prevent the spread of Varroa mite past the possibility of eradication (Plant Health Australia 2009).

In 2011 PHA established the Varroa Continuity Strategy Management Committee (VCSMC) funded by the Australian Government Department of Agriculture to support honey bee pollination dependent industries and the beekeepers of Australia. The VCSMC looked closely into the intra- and inter-state movement restrictions that may result due to an incursion of Varroa mite. In the event of a Varroa mite incursion, governments would introduce a restricted area and a control area around the identified infected premises. Within the restricted area all managed apiaries would be quarantined and movement out of the restricted area will be prohibited. The control area would be a larger declared area around the restricted area(s) and initially may be as large as a state or territory (Commonwealth of Australia 2011).

However, further investigation is needed to understand the impact these movement controls would have on the ability to continue with intra- and inter- regional paid pollination services. Increased industry specific planning and preparedness for a potential incursion of Varroa mite will provide a mechanism for growers, industry stakeholders and governments to assess current biosecurity practises, identify gaps and opportunities, and ensure the continued growth and stability of pollination dependent industries.

In 2013, PHA was further commissioned by Rural Industries Research and Development Corporation (RIRDC) and Horticulture Australia (HAL) to explore how the impact of honey bee movement restrictions potentially implemented as a result of Varroa mite incursion would affect pollination dependent industries[5]. Combining these findings with those from the 2009 pollination report will enable for an effective analysis of the potential impacts that state and regional quarantine responses may have on hive movements and the availability of pollination services. This project also aims to understand the reliance of pollination dependent industries on native bees, wild honey bees and managed honey bees for pollination as well as the alternatives to bee pollination that are available.

Information was collected from peak industry body representatives and growers from 10 participating industries through an online census. The peak industry bodies targeted were: Almond Board of Australia, Apple and Pear Australia, Avocados Australia Ltd, Cherry Growers Australia Inc., Australian Melon Association, Canned Fruit Industry Council of Australia, The Australian Prune Industry Association, Summerfruit Australia, AUSVEG Limited and Onions Australia. The links to the census were emailed to peak industry body representatives who were encouraged to forward it on to their members. There were two censuses available – one for the peak industry body (Appendix 1) and another tailored for growers (Appendix 2).

The completion of one census per peak industry body was all that was required to represent the industry's views. The grower census was to give an "on the ground" perspective and therefore required a large number of responses from as many growers

[5] This report only covers the pollination dependent industries that funded this project through HAL and RIRDC

as possible. However, response numbers received per industry were varied with some industries receiving no responses (Figure 1). This sporadic level of data meant that all interpretation undertaken in this report can only give an indication of the views of a particular industry and only represents a snap shot in time.

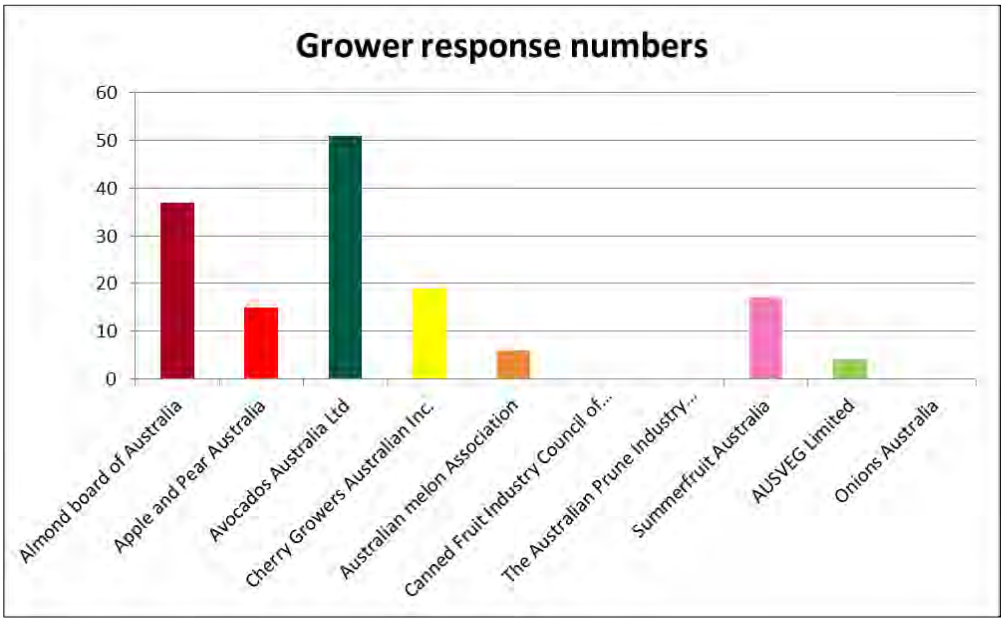

Figure 1: The individual industry level of responses to the grower pollination census

Industry analysis

Almonds

Represented by Almond Board of Australia

Varroa impact rating: HIGH

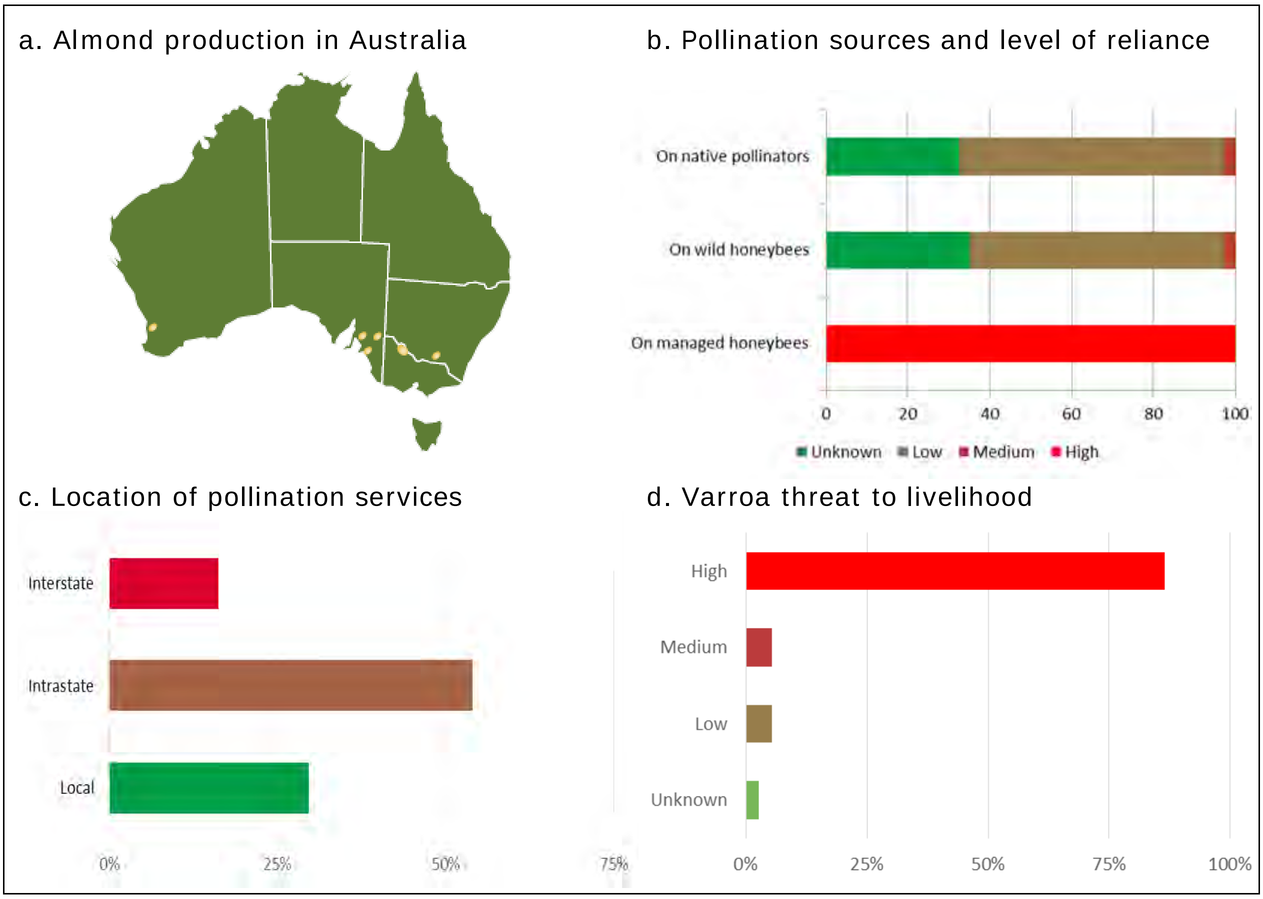

Figure 2 (a-d): Snapshot of the pollination dependence of the almond industry (data from 37 growers)

The Australian almond industry is located in South Australia, Victoria, Western Australia and New South Wales (Figure 2a). The majority (60%) of almond orchards in Australia are located in Robinvale, Victoria. A total of 30,259 hectares of land is dedicated to the cultivation of almonds with an estimated farm gate value of more than $250 million (Plant Health Australia 2012a). It is forecast that the Australian almond industry will increase its share of current global production from 3% to 6% surpassing Spain, to become the world's second largest almond producer in the next few years (Cunningham 2012a). The majority of commercial almond cultivars in Australia are self-incompatible and typically require the joint planting of at least two inter-compatible and simultaneously blooming cultivars as well as the presence of insects to transfer pollen (RIRDC 2008a). Currently the strategy employed by the industry is to mix early and late flowering cultivars to ensure overlap with the premium variety (Cunningham 2011).

The pollination requirements of almond growers are provided for solely by paid pollination services (Figure 2b). The location of hired hives varied, however the majority (80%) of the hives used by the growers who responded to this census were sourced from within the state that the growers are located (Figure 2c). This census result is contradictory to industry anecdotal evidence that suggests that a large proportion of hives used for almond pollination are sourced out of state. The growers who responded to the census believe the access of hives within their own state means that if border restrictions were put in place, they would still have access to sufficient pollination services to successfully pollinate their crops. A minority of almond growers (16%) would have problems in sourcing pollination services as they are located close to state borders and use inter-state pollination companies because of their location. Currently, almond producers pay an average of $65 per hive for pollination services; however responses regarding pollination costs varied from $6 per hive to $80 per hive. The average stocking rate for almond growers was 5.7 hives/ha which is slightly less than documented current practise of 7.5 hives/ha (Cunningham 2012a). Overall almond growers feel that the current costs of pollination services are already putting a strain on the viability of the industry.

The demand for honey bees by almond growers is at its peak in August with requirements estimated at over 23,000 hives (Plant Health Australia 2009). An important aspect to consider when determining the availability of hives for almond pollination is the location of hives in July. Throughout the year pollination providers will transport hives to source nectar and pollen before fulfilling pollination contracts to ensure bees are healthy and robust enough to be effective pollinators. In the 2009 pollination report, beekeepers indicated the location of the majority of hives in July 2008/2009 was determined by a Spotted gum (*Corymbia maculata*) flowering event near Batemans Bay NSW (Figure 3). This map was developed from the responses to the 2009 pollination report and is not representative of the entire industry; however it gives an idea of the location of hives at this time.

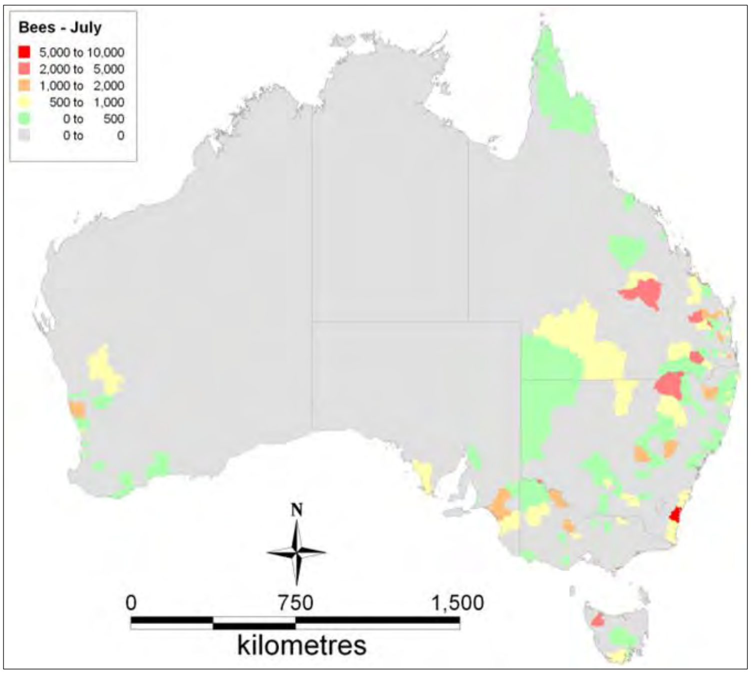

Figure 3: Location of hives July (2008/2009) (Plant Health Australia 2009)

If quarantine restrictions were implemented when hives were located as depicted in Figure 3, a large amount of hives would have been unable to enter Victoria to provide the required almond pollination service to the Robinvale area. However, care needs to be taken when relying on this information to develop contingency plans. The location and availability of flora varies yearly and with seasonal conditions which can dictate flowering events sometimes 18 months in advance. Therefore even with this information (representing a snapshot in time), there is no definitive way to determine future flowering events that beekeepers will utilise prior to fulfilling almond contracts or if they will choose to overwinter their hives instead. These reactive decisions bee keepers make to align their hives with flowering events therefore determines where hives will be located prior to moving into almond growing areas. For example, in July, the top five native floral resources utilised by beekeepers are banksia, ironbark, spotted gum, tea tree and white box (Plant Health Australia 2009). Trying to use this information to hypothesise beekeeper location in July is complicated as the location of these floral resources is varied as seen in Figure 4 and hive movement to these areas depends on flowering events (dependent on seasonal conditions) and the suitability of these events for honey production. There is also secrecy among beekeepers as to where they plan to move their hives for floral resources, as having a monopoly on a flowering event can be very important in determining the economic viability of a beekeeper's business.

In the event of a Varroa incursion, where the availability of wild honey bees and paid pollination services may be decreased, almond growers would be severely affected as 95% of growers have no alternative pollination techniques they could quickly employ. The greatest impact of a Varroa mite incursion would be the ongoing increases to the cost of paid pollination services. The threat of Varroa mite is rated high (Figure 2d) however 92% of growers make no specific biosecurity requests of their pollination service providers to mitigate risks to honey bee health. Almond growers believe that the beekeepers are responsible for ensuring the biosecurity of their own bees. Only one almond grower requires beekeepers to sign a specialised contract that states that all hives have arrived pest and disease free, meeting a minimum strength standard and are inspected by a 3rd party upon delivery. This identifies a gap in industry best practise as growers do not know what condition the bees are in when they receive them and this could affect their ability to effectively pollinate their crops.

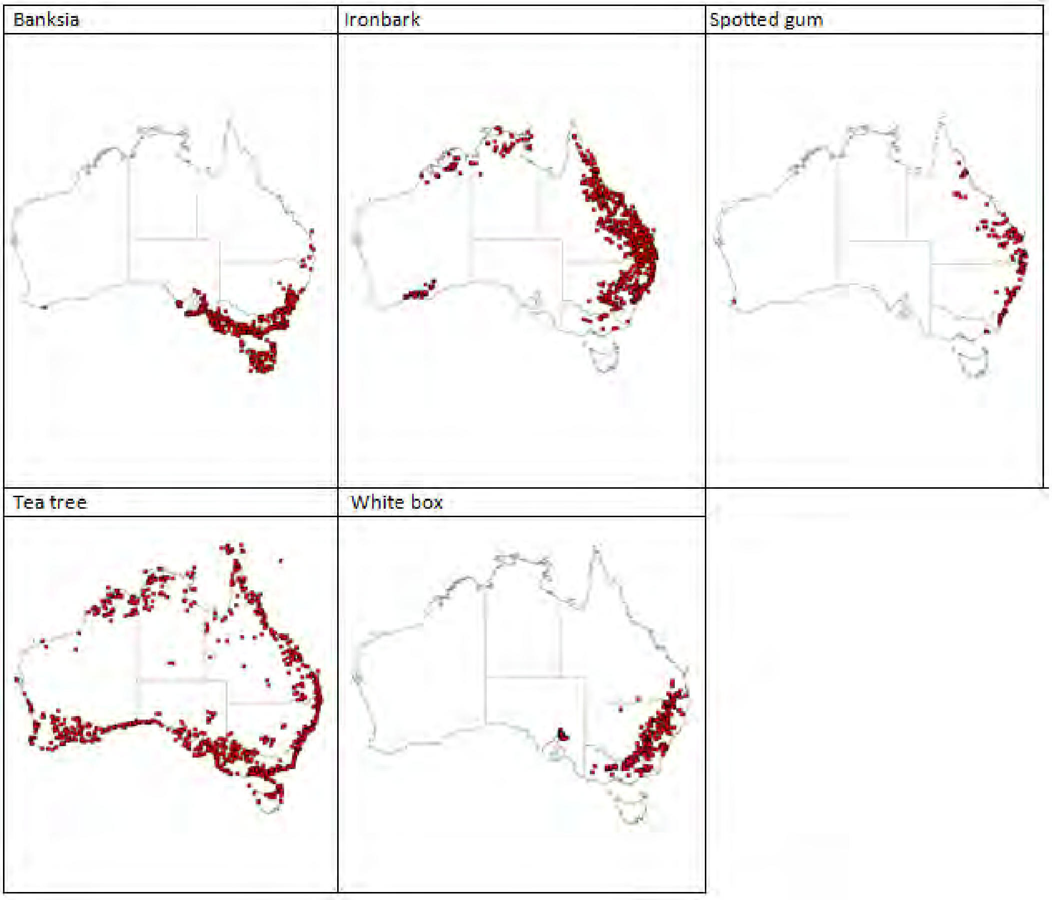

Figure 4: Location of the top 5 native floral resources for beekeepers

Alternative pollination techniques for almonds together with improving hive management and cross pollination methods are Research and Development priorities for the Almond Board of Australia. Recent projects have found that hive placement is more important than honey bee density with fruit set efficiency increasing when hives are arranged in small placements relatively close together rather than large placements far apart (Cunningham 2012b). High bee density has been associated with poor fruit set which indicates that flooding orchards with large quantities of honey bees is not an effective mechanism to increase almond yield (Cunningham 2012c). Research is also currently being conducted into self-compatible almond varieties that would not require vector assisted pollination, however currently these varieties are not yet commercial (Cunningham 2011). A Varroa incursion simulation for the almond industry planned for 2014 will provide further insight into the development of a contingency framework for the industry.

Apples and Pears

Represented by Apple and Pear Australia

Varroa impact rating: HIGH

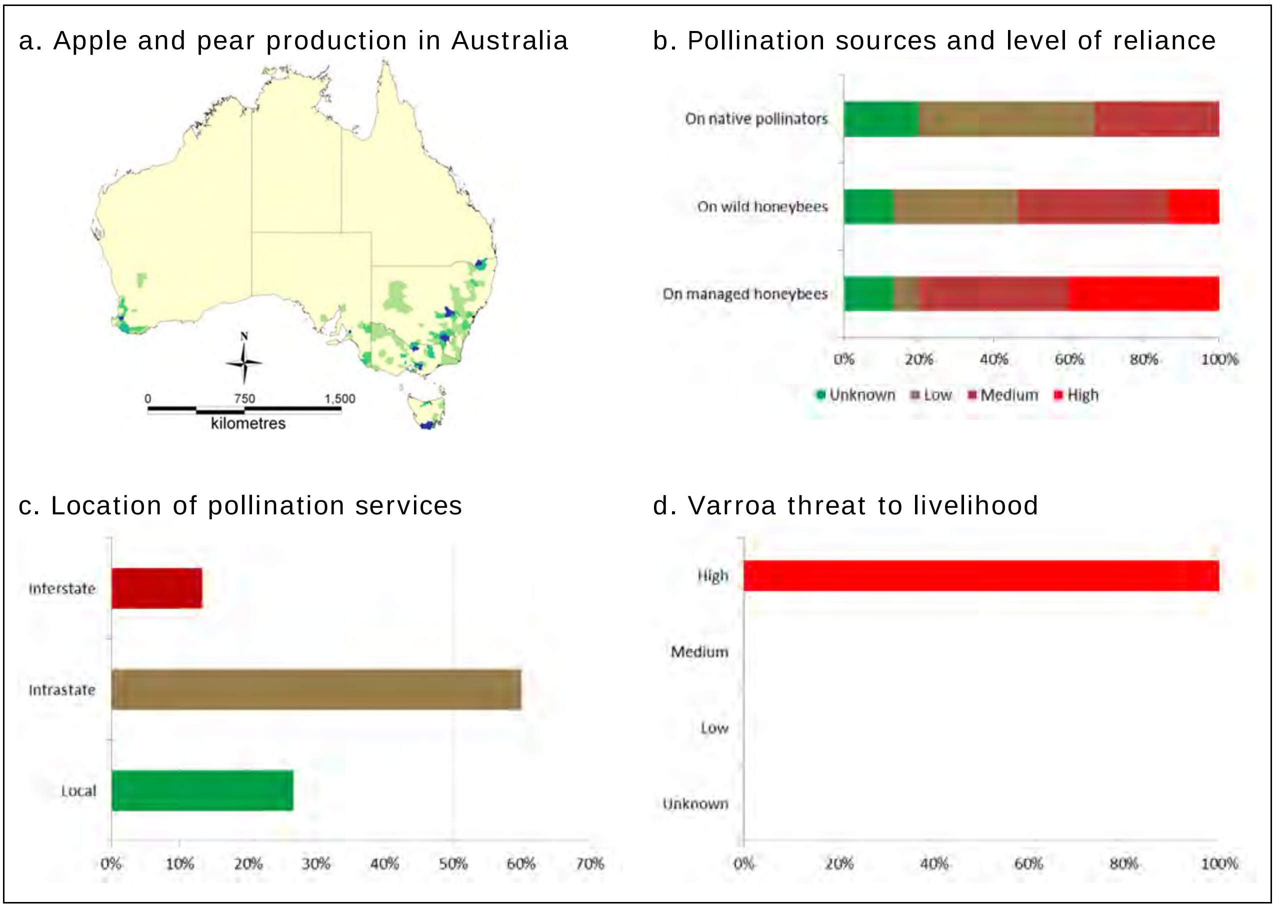

Figure 5 (a-d): Snapshot of the pollination dependence of the apple and pear industry (data from 15 growers)

The apple and pear industry is Australia's largest fruit industry valued at over $770 million (Plant Health Australia 2012a). The Australian apple industry is mostly aimed at the domestic market with around 90% of production consumed in Australia. However the export market is growing with major export markets including United Kingdom, Malaysia, India, Singapore and Sri Lanka (RIRDC 2008b). Australia produces approximately 140,000 tonnes of pears per year with the majority of production concentrated in Victoria (RIRDC 2009b). The major production areas for apple and pears in Australia are based in Queensland, New South Wales and southern Victoria with small production areas in the Adelaide Hills and Perth (Figure 5a) (Plant Health Australia 2010). Both apples and pears are considered self-infertile and require cross-pollination with another variety for the fruit to set (RIRDC 2008b). Honey bees as pollinators are known to be selective in the flowers they visit, as they choose flowers which best meet their energetic requirements (Abrol 1993). Apples are considered to be a highly attractive floral resource to honey bees however pears are not considered as attractive due to the low volume of nectar in pear flowers in conjunction with low sugar concentration (RIRDC 2009b). Due to pears being less favourable to honey bees, pear growers require greater hive density to ensure sufficient pollination and are charged higher rates due to honey losses.

There is a strong requirement of paid pollination services for apple and pear production (Figure 5b) with a small amount of pollination services believed to be completed by wild honey bees. Conversely, the peak industry body feels that a large amount of pollination occurs via wild honey bees, sometimes acting as the sole method of pollination. Some growers noted that the reliance on native bees varied year to year with large numbers sometimes observed in the crop. One grower believes that a large amount of pollination occurs incidentally due to hives located in a national park that is close to the property.

On average, the stocking rate of 6 hives per hectare is used for the pollination of apples and pears with the majority of hives (60%) sourced from within the same state as production (Figure 5c). There is increasing pressure for growers to produce fruit that is not only high in quality but also fits specific colour and shape requirements. These selective requirements means honey bees need to pollinate a high percentage of flowers to produce enough ideal fruit to be profitable for growers with over 40% of respondents feeling that their pollination requirements will increase because of this. The peak industry body also notes that acreage and orchard density is increasing in the apple and pear industry which will also increase pollination requirements. The dependence of the apple and pear industry on pollination by wild honey bees and commercially managed honey bees means that a Varroa mite incursion would have a significant impact on the industry (Figure 5d). Apple and pear growers believe a Varroa mite incursion will have a high impact on their industry as there are no viable pollination alternatives currently available and no current funding for research into this area.

Avocados

Represented by Avocados Australia

Varroa impact rating: HIGH

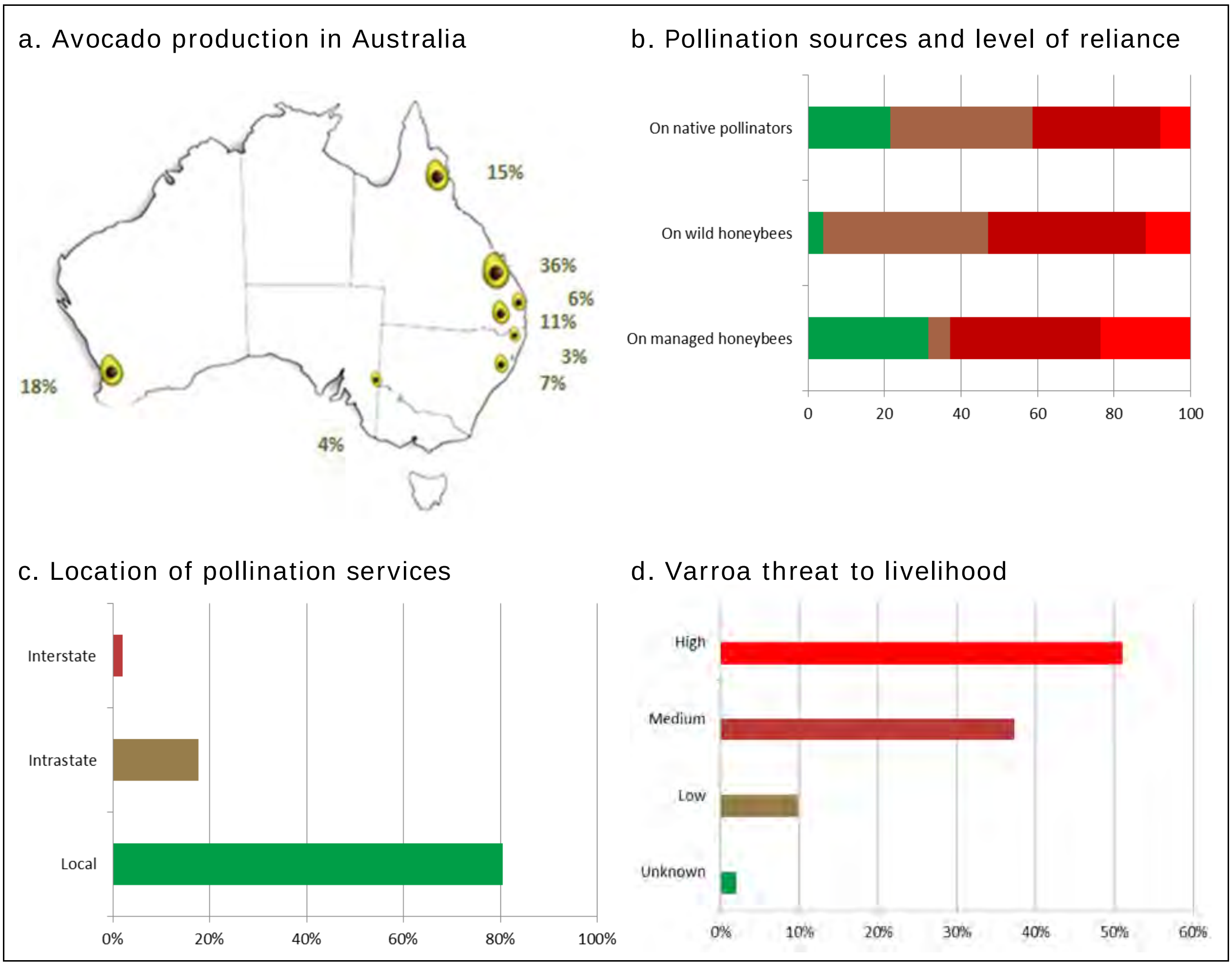

Figure 6 (a-d): Snapshot of the pollination dependence of the avocado industry (data from 51 growers)

The Australian avocado industry comprises of around 1,000 growers and several large corporate suppliers encompassing 6,900 hectares of avocado orchards (Plant Health Australia 2011a). Queensland dominates Australia's avocado production with the north, central and south east of the state producing over half of the total 51,113 tonnes (Figure 6a) valued at $183 million. The key international markets that import Australian avocados are Singapore, Thailand, the United Arab Emirates and Hong Kong (Plant Health Australia 2012a). The yield of avocados is dependent upon insect pollination as avocados flower twice– the first functionally as a female flower and the following day functionally as a male flower (RIRDC 2009c). This also requires varieties/cultivars that flower at different times to be interplanted to allow for pollination to occur (Ish-am and Eisikowitch 1998).

The pollination of Australian avocados currently relies on a mixture of native bees, wild honey bees and commercial honey bees. While only 11% of growers rely exclusively on wild honey bees for the pollination of avocados, 41% report that over half of their pollination requirements can be attributed to this source (Figure 6b). Native bees and other insects such as hover flies and beetles are also present in avocado orchards and play a role in the pollination of avocado flowers. However, avocado growers still rely heavily on honey bee pollination services with 63% of growers using pollination services in high or medium quantities. There are also known cases of incidental pollination as some avocado growers allow beekeepers to use their orchards as a nectar resource to build up hives as well as providing a safe location for hive storage. Avocado growers that rely on this incidental pollination acknowledge that this form of pollination service will not always be available to them and they will need to invest in alternatives in the future.

Currently, the pollination of avocado crops is obtained from hives located within the same state and region as production (Figure 6c). If state borders were closed due to a Varroa mite incursion, the majority of growers believe they would still have access to the required amount of hives to pollinate crops at current levels. However there is an expectation that the production area of avocados (especially in South Australia) will increase which in turn will increase the pollination requirements. In the event of a Varroa mite incursion, avocado growers indicate that the reliance on native bees and other pollinating insects will increase to make up for the reductions in wild honey bee populations. There is also a belief that in the absence of wild honey bee populations, native bee colonies will increase and fill the pollination void. However, it should be noted that the arrival of European honey bees to Australia did not severely impact the population of native bee species indicating that the reverse of this would most likely be the same (Paton and RIRDC 1999). The threat of Varroa mite to the avocado industry is still considered high by over 50% of respondents (Figure 6d) even with the expected increase in the availability of native bees as pollinators. There has been no industry specific planning for Varroa mite with a large reliance still on the honey bee industry themselves to maintain bee health and biosecurity.

Cherries

Represented by Cherry Growers of Australia

Varroa impact rating: HIGH

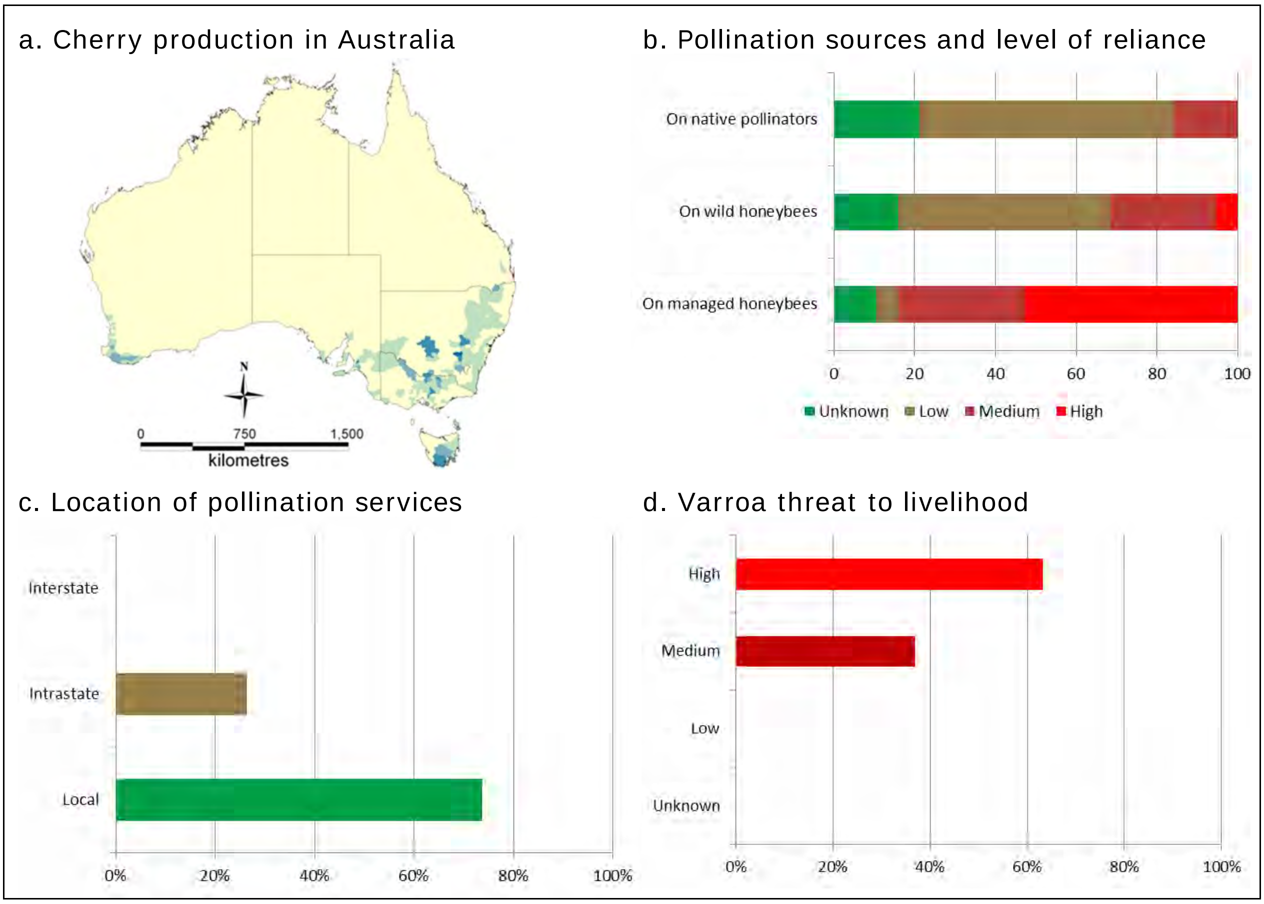

Figure 7 (a-d): Snapshot of the pollination dependence of the cherry industry (data from 19 growers)

The Australian cherry industry comprises of an estimated 575 growers producing cherries across almost 3,000 hectares (Plant Health Australia 2011b). Cherries are grown in all states and territories except the Northern Territory (Figure 7a) and is currently valued at approximately $120 million with the majority sold domestically (Plant Health Australia 2012a). Cross-pollination is required to ensure a satisfactory crop of cherries with studies showing that 97% of the pollinators that visit cherries are honey bees (RIRDC 2008c). This may be due to the fact that cherry blossoms occur too early in the year for other insect pollinators to be in high enough density to be adequate pollinators of cherry trees. Without effective pollination, cherries will only develop to the size of garden peas (Mcgregor and Bean 2009).

In general, wild honey bees account for a proportion of cherry blossom pollination yet over 50% of cherry growers depend entirely on commercial pollination services to pollinate their crop (Figure 7a). There was some response regarding reliance on bumble bees however, bumble bees were not considered in this report as they are only found in Tasmania.

All hives sourced for the pollination of cherry trees come from within the same state as production (Figure 7c) with pollination services averaging in costs of $130 per hive. The cherry industry is not expected to expand which indicates that there will be no increases in pollination requirements. However, there are expectations that pollination service prices will continue to increase as there are often more attractive flora for beekeepers during this period. This is because the hive densities required in cherry orchards means bees are unlikely to store any surplus honey. Some growers have started owning hives in a bid to overcome this problem of expensive pollination services. Overall Varroa mite is considered a high threat to the livelihood of cherry growers (Figure 7d) as cherries in Australia are directly dependent on honey bee pollination. There are currently no commercially available alternative pollination techniques available to the cherry industry and there is no industry specific Varroa mite incursion plan.


Melons

Represented by Australian Melon Association

Varroa impact rating: HIGH

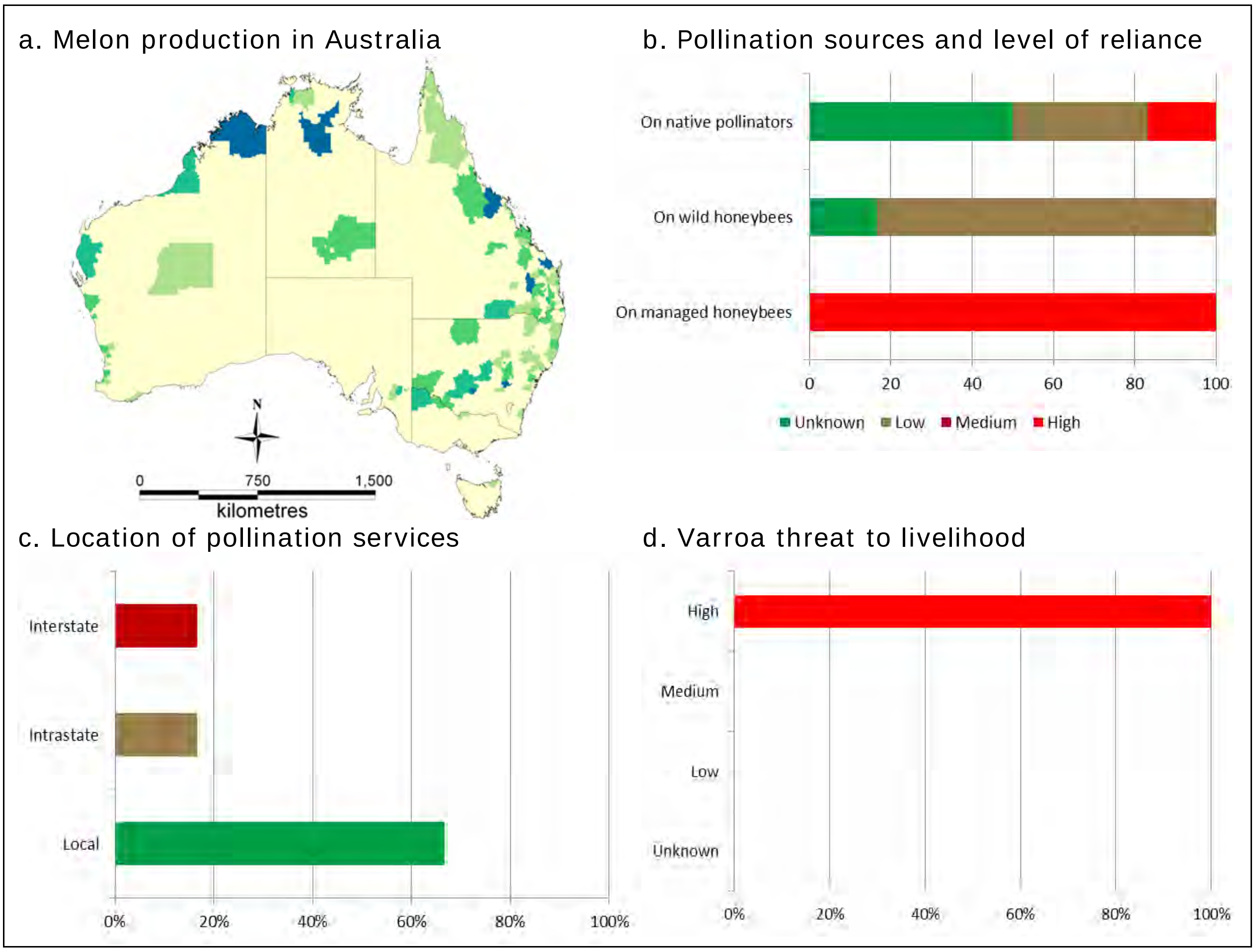

Figure 8 (a-d): Snapshot of the pollination dependence of the melon industry (data from 6 growers)

The Australian melon industry produces approximately 217,000 tonnes of melons annually across an area of around 8,500 hectares (Plant Health Australia 2012a). Melon production encompasses every state and territory except the ACT (Figure 8a) however around 50% of all Australian melons are grown in Queensland alone (RIRDC 2008d). The Australian melon industry is valued at approximately $150 million per annum and involves 400 growers who predominately produce watermelon, honeydew and rockmelon (Australian Melon Association Inc. 2008). The flowers of melons are exclusively pollinated by insects with honey bees recorded visiting melons at the peak flower opening times (Mcgregor and Bean 2009). Honey bees are critical for the transfer of pollen with studies indicating that little to no pollination occurs in melons without insect vectors (RIRDC 2008d).

Pollination services accounts for all the pollination needs of the melon industry with a slight contribution made by native bees (Figure 8a). The majority (74%) of commercial hives employed by the melon industry not only come from within the state requiring them but also from within the same region (Figure 8c). This local sourcing of hives indicates that if state borders were closed due to a Varroa mite incursion, melon growers would still have access to their required pollination services.

There are currently no viable alternatives to pollination for melons with seedless varieties still requiring vector pollination. Both the peak industry body and melon growers believe the threat of Varroa mite to the industry is high and could affect the livelihood and the ongoing viability of the industry (Figure 8d). There is currently no Varroa mite contingency planning conducted in the melon industry.

Stone fruit: apricots, peaches, nectarines and plums

Represented by Summerfruit, Canned fruit and Australian Prune Industry Association

Varroa impact rating: HIGH

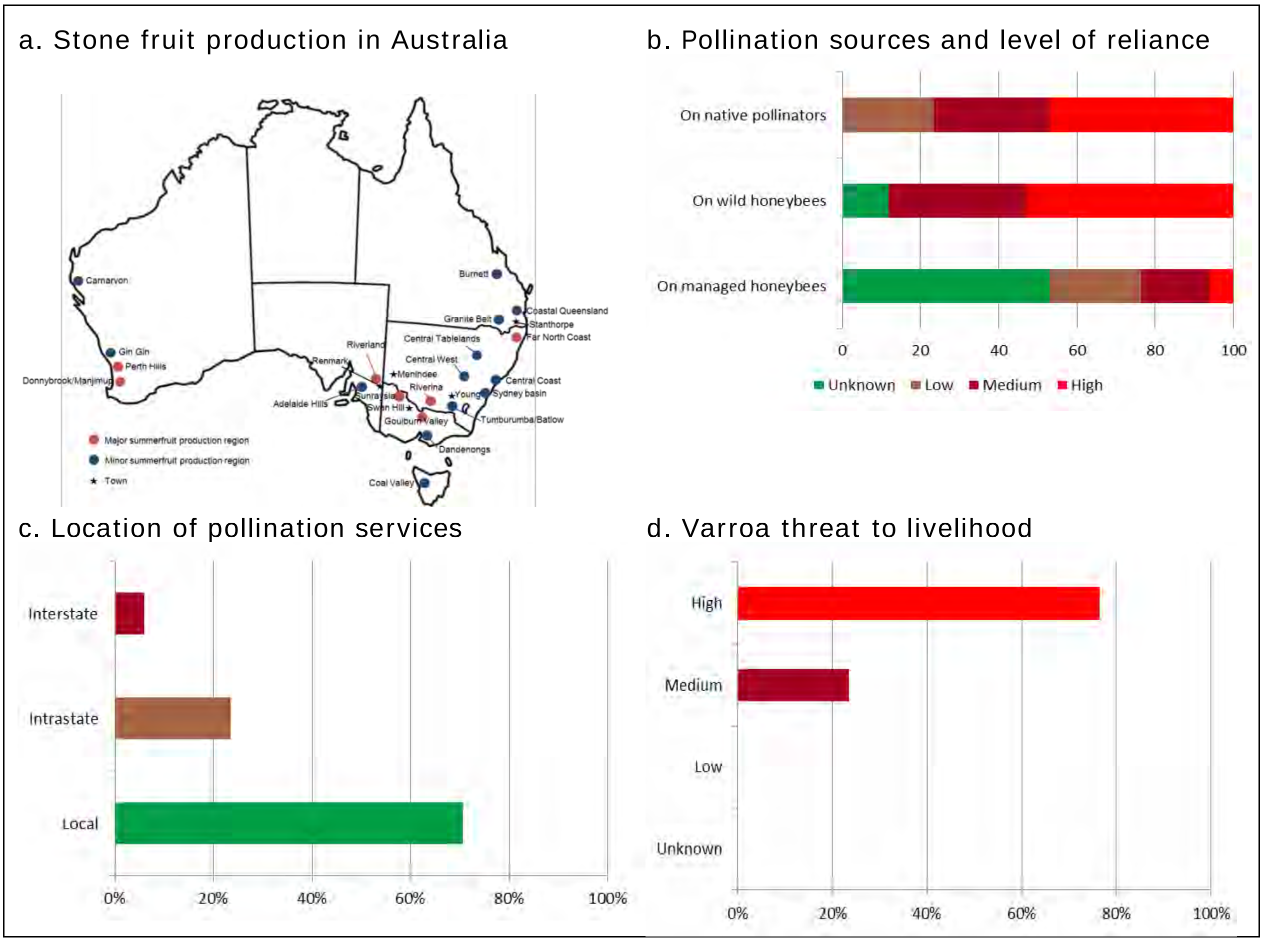

Figure 9 (a-d): Snapshot of pollination dependence of the stone fruit industry (data from 17 growers)

Fresh stone fruit is represented by the Summerfruit industry which is valued at around $300 million and produces 175,000 tonnes of fresh fruit per annum (Plant Health Australia 2012a). Stone fruit is predominantly grown in subtropical and temperate climates within Australia (Figure 9a) with the majority (72%) of produce coming from Victoria (Plant Health Australia 2011c). The Canned fruit industry is primarily based in the Goulburn-Murray Valleys of Victoria and has an annual farm gate value of $37 million (Plant Health Australia 2012a). There are around 70 farmers who grow plums to produce 5 tonnes of prunes annually and are found predominately in the temperate areas of Young and Griffith in New South Wales (RIRDC 2009d).

There is limited data on the pollination requirements of apricots, however it has been indicated that apricots must be cross-pollinated within the specific time of flowering which is often short and lasts less than two days (RIRDC 2008e). The sticky pollen of the apricot requires insect pollinators to carry out pollination as relying on wind as the primary pollinator is ineffective (Mcgregor and Bean 2009). The pollination dependence of peaches and nectarines varies due to the varieties available being either self-fertile or self-sterile. There is strong evidence however, that a satisfactory commercial crop cannot be obtained unless adequate numbers of insects pollinate the crop, regardless of variety (RIRDC 2009a). The flowers of peaches and nectarines are considered highly attractive to honey bees and are considered an easier crop to pollinate as only one ovule must be fertilised for fruit to form compared to hundreds of ovules needed in other fruits such as melons or papayas (Mcgregor and Bean 2009). Most variety of plums (including those dried into prunes) are self-incompatible and rely on honey bees to transfer pollen which has been documented to increase yield by 150% (compared to plums that had no insect vectors) (Mcgregor and Bean 2009). Honey bees have been recognised as the primary pollinating agent for plums since the early 1900s (RIRDC 2009d).

Half of the stone fruit growers believe wild honey bees are responsible for the pollination of their entire crop while over 40% believe their pollination requirements are met by native bees. Overall, only a small percentage (less than 6%) of growers were dependent on commercial pollination services (Figure 9b) which are located locally (Figure 9c). The future pollination requirements of the stone fruit industry is not uniform as only 30% expect an increase to their pollination requirements as they expand their production area. The prune industry is expected to actually decline in the next few years and therefore sees the current reliance on wild honey bees as economically viable. No growers managed any hives of their own and due to a lower dependence on pollination services, the majority of stone fruit growers feel they would be able to pollinate their crops sufficiently in the event of honey bee movement restrictions. However, due to the reliance on wild honey bees for pollination, any reductions in wild honey bee populations as a result of Varroa mite would have a great effect on all the stone fruit industries (Figure 9d). There is currently research being conducted into self-fertile varieties of stonefruit which may overcome the dependence of these industries on pollination.

Vegetables and vegetable seed

Represented by AUSVEG Limited

Varroa impact rating: MEDIUM/HIGH

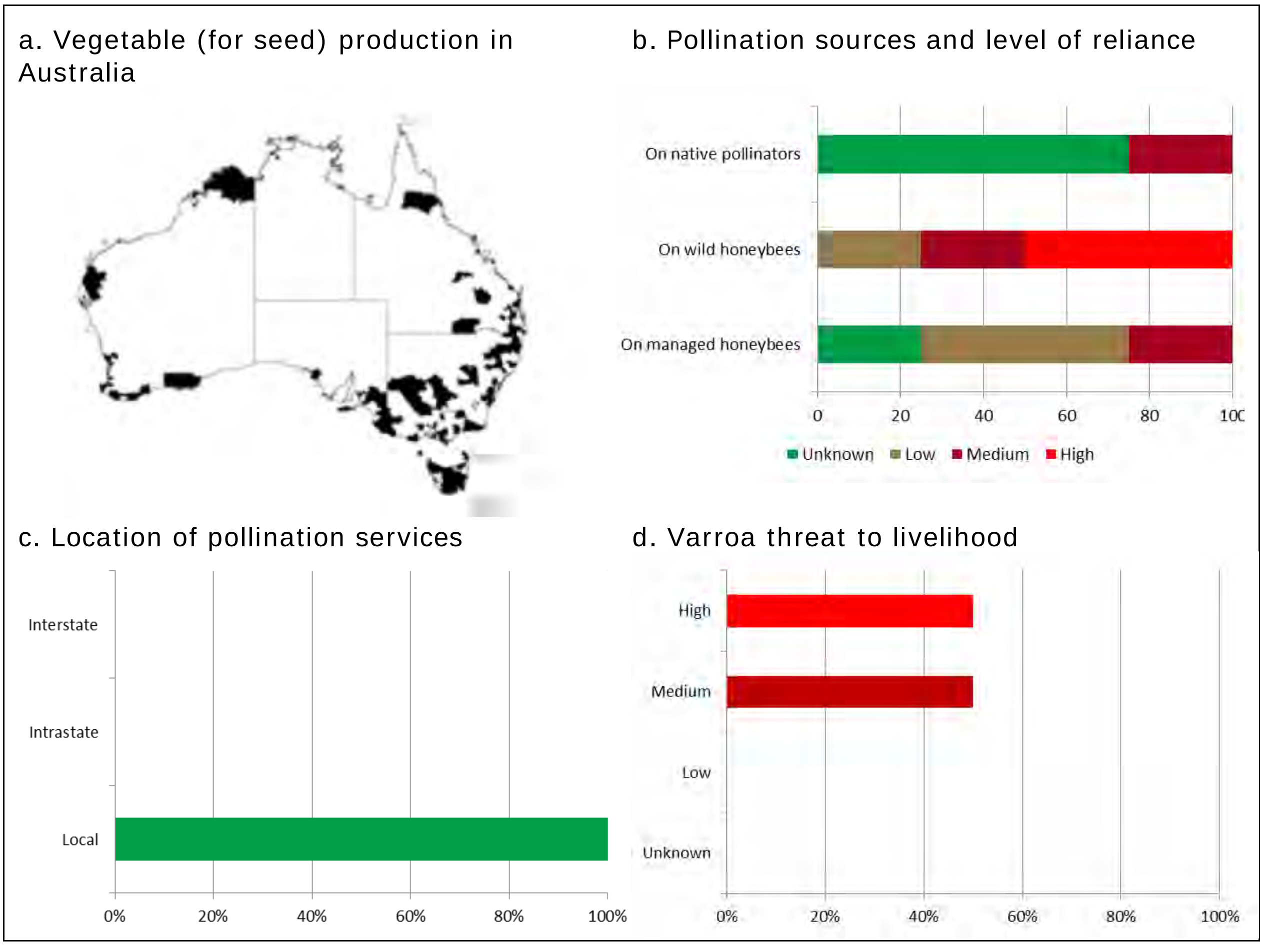

Figure 10 (a-d): Snapshot of pollination dependence of the vegetable for seed industry (data from 4 growers)

Vegetables are valued at $2.8 billion and are grown across Australia and largely sold for the domestic market (Plant Health Australia 2012a). Pollination is not essential for all crops represented by AUSVEG limited and is only required for cabbage (for seed), carrot (for seed), cauliflower (for seed), cucumber, pumpkins, potato (for seed) and zucchini. Pollination dependent vegetables and vegetable seed are grown in all states except the Northern Territory (Figure 10a). The pollination requirement varies depending on the vegetable, for example, cabbages and radishes require cross-pollination while others only require pollination to increase yield (RIRDC 2008f).

There was a strong reliance (50%) by vegetable growers on using wild honey bees to pollinate their crops. From the growers who completed the census, no one relied exclusively on paid pollination services (Figure 10b). The pollination services used in low-medium quantities were sourced locally (Figure 10c). The low reliance on pollination services can perhaps be attributed to vegetable growers owning and managing their own hives which was the practise of half the respondents. There are currently some alternatives to honey bee pollination available including the use of mechanical vibration and air blast pollination techniques. Yet neither of these options are as effective as honey bee pollination (Hanna 2004). The reliance of some vegetables growers on wild honey bees means that an incursion of Varroa mite in Australia would severely threaten the pollination of some vegetable corps. However, the overall effect on the entire vegetable industry would be minor, as only a sub-set of crops requires pollination.

Onion seed

Represented by Onions Australia

Varro impact rating: HIGH

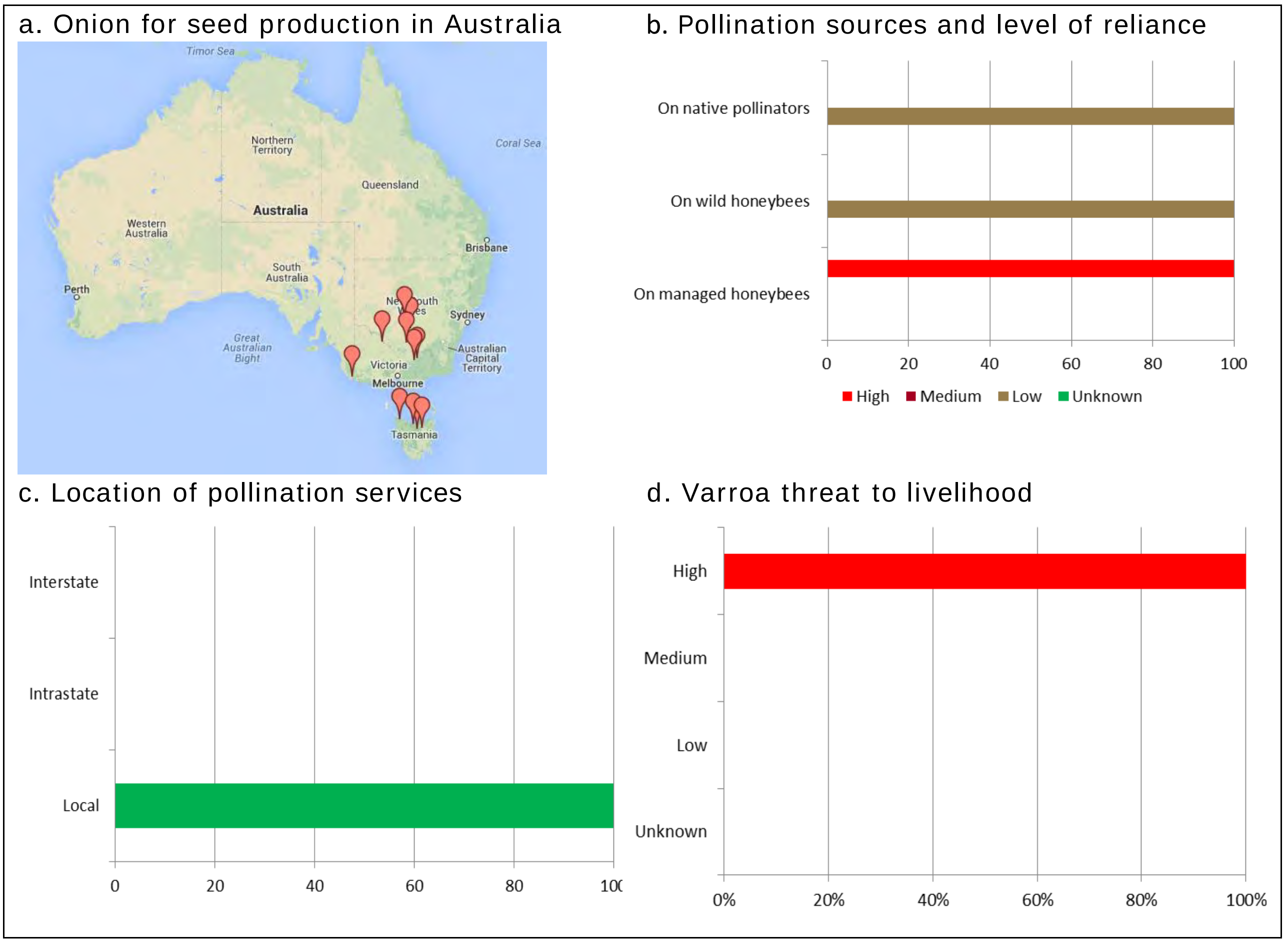

Figure 11: Snapshot of pollination dependence of the onion seed industry (data from peak industry body representative)

Onions in Australia are grown on 5,000 hectares with production reaching 250,000 tonnes (Plant Health Australia 2012a). Onions are the fourth largest vegetable crop in Australia with 248 growers with the major bulb production occurring in South Australia and Tasmania (Plant Health Australia 2012c). Onion production in Australia is valued at $274 million with exports accounting for $26 million (Plant Health Australia 2012a). When onions are planted for production, the plant is allowed to reach the proper size or condition before being harvested without pollination taking place and the plant produces no seeds (Mcgregor and Bean 2009). Onions that are grown for 'seed only' require pollination, with studies showing that the yield, quality and emergence rate of onion seed being significantly dependent upon pollination (RIRDC 2008f). In Australia, an estimated 400 hectares is used for onion seed production (Plant Health Australia 2012a) located in New South Wales, Victoria, South Australia and Tasmania (Figure 11). Self-pollination within onion flowers does not occur and therefore insect pollinators are required in high density to provide adequate pollination. Onions as a floral source are considered to be low in attractiveness to honey bees which limit the ability of growers to rely on native or wild honey bees as pollinators (Mcgregor and Bean 2009).

Unfortunately there were no grower responses to the census and all evaluation is based on the response on behalf of the peak industry body. All onion seed crops have hives supplied at flowering to ensure pollination, with all hives coming from within the region of production. The industry's pollination requirements are not expected to increase which means future expenditure on commercial pollination will depend exclusively on future hive costs. Very few industry members grow onion for seed crops with the majority of seed crop grown by seed companies. However, a Varroa mite incursion would severely impact the whole industry as onion seed crops provide seed for the industry to use in the production of onion as a crop.

Overall industry pollination dependence and Varroa mite preparedness

Pollination dependent industries do not have contingency plans available to mitigate the effects of Varroa mite on the availability of honey bees for pollination. This overall lack of preparedness could stem from a reliance on the honey bee industry to prepare for and respond to all bee pests and diseases and consistently maintain the availability of pollination services. However, as pollination dependent industries rely heavily on commercial pollination services to maintain adequate pollination of their crops this responsibility should be shared. This dependence necessitates the involvement of these industries in maintaining the health of wild and managed honey bees throughout Australia.

The distribution of hives around Australia varies to correspond with the levels of floral resources available for honey production and to meet the seasonal demand for pollination services. It is therefore not only hard to pinpoint their exact location at any time of the year but also difficult to predict future movements. The mobility of the beekeeping industry is an important factor to consider when planning ongoing access to seasonal nectar flows and to ensure pollination contracts can be fulfilled. Therefore, at the time of an incursion, previously used pollination services may not be available if pollination providers are restricted by state or regional quarantine controls. Figure 12 shows an example of the movement some hives undergo, with this particular beekeeper moving hives across states and multiple regions. The use of quarantine restrictions in the event of a Varroa mite incursion makes all pollination dependent industries vulnerable and could result in a significant reduction in the yield and quality of produce.

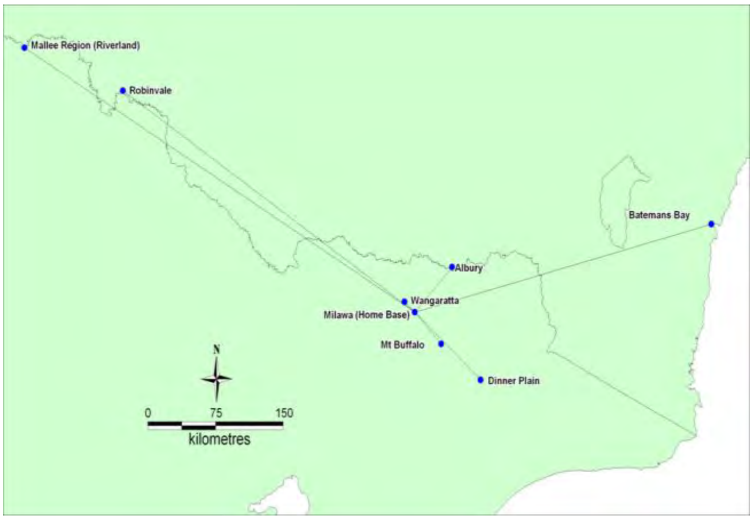

Figure 12: Movement of commercial hives by a Victorian beekeeper (Plant Health Australia 2009)

All industries projected some level of industry growth which would increase their pollination requirements. Participants also expected pollination costs to increase regardless of whether their requirements increased or not. The increase in costs is seen to be due to inflation and a monopolisation of the industry by a few key commercial pollination companies. The current costs associated with employing pollination services are already seen as a threat to the long term viability of industries. If Varroa mite were to enter Australia, these costs are expected to increase exponentially. There would be changes within the beekeeping industry to try and manage the ongoing effects of Varroa mite on honey bee health and numbers. These changes include increased management requirements to maintain healthy hives which would in turn make the job of beekeepers more labour intensive and costly. This would force beekeepers to pass on these increases in business costs to the grower employing their services. With Varroa mite expected to destroy 95% of the wild honey bee population, industries that have in the past managed without hiring any pollination services would have to employ commercial hives to maintain their current level of pollination. Due to many different crop types requiring pollination at similar times of the year, any increase in pollination requirements would also increase the amount of hives needed overall.

It is clear from the census responses that industries understand the important role that honey bees play in maintaining high levels of crop production and quality. Pollination dependent industries correlate the access and use of pollination providers to the viability of their industry; however there is currently limited investment from these industries towards protecting the honey bee industry. Through the census, only one respondent out of the total 156 questioned requested additional biosecurity practises from their pollination providers to ensure honey bee biosecurity was maintained.

With the potential impacts of Varroa mite well documented from past incursions overseas, research into alternative pollination techniques, selective plant breeding of self-fertilising plants and general honey bee biosecurity needs to be a priority for pollination dependent industries. Many industry R&D programs have to cover a wide variety of issues with limited funds which are usually allocated to pests that directly impact on crop health and production. This and the fact that wild honey bee numbers are strong and that pollination services are currently readily available may indicate the reason for absence of investment in this area. However, the overall lack of available alternatives to honey bee pollination means honey bee biosecurity and Varroa mite preparedness are crucial to the stability of all Australian pollination dependent industries.

Case study: New Zealand

Australia is in the unique position of being the only mainland continent to be free from Varroa mite which allows for useful insight into overseas experiences with Varroa mite. New Zealand has a large beekeeping sector and has had the most recent experience with dealing with Varroa mite. Varroa mite was first detected in New Zealand in 2000 with the initial delimiting survey finding more than 20% of apiaries were infected in areas surrounding Auckland international airport and more than 10% were infected in the upper North Island (Martin et al. 2005). The Ministry of Primary Industries imposed movement controls within defined zones and conducted targeted sampling. An epidemiology study of the response found infested apiaries were highly clustered which supported the theory of radial spread (Martin et al. 2005). Due to the density of infestation in certain areas the results suggested that Varroa mite had probably been present in New Zealand for a number of years prior to detection. It was concluded that national eradication of Varroa was unlikely to succeed due to the:

- Lack of sensitivity of the testing methods
- Inability to detect infected premises before local spread had occurred
- Inability to eradicate Varroa mite from wild honey bee colonies
- Spread via beekeeper assisted movements
- Potential non-compliance by beekeepers (Plant Health Australia 2013b).

The Ministry of Primary Industries implemented a management strategy which involved the North Island to be separated by 'North Island Line' to restrict movement south. The National Pest Management Strategy was developed with key elements such as the maintenance of movement controls, education on Varroa mite spread and continuation of the surveillance program of outlier Varroa mite incursions. The National Pest Management Strategy allowed for shifting management zone to be established and adjusted based on surveillance and mandatory reporting programs. In 2006 Varroa mite spread to the South Island which overtime led to the dismantling of the movement control lines as preventing the further spread of Varroa mite was unfeasible due to the number of beekeeping operations already affected.

Key lessons from the New Zealand experience:

- The New Zealand national beekeeper database held details of all registered hives and beekeepers which enabled authorities to accurately and quickly locate potentially infected hives and at-risk beekeepers
- The New Zealand beekeeping industry is largely stationary due to limited movement involved in accessing nectar flows – this meant that the North Island line was an effective means of slowing the spread of Varroa mite
- The effective implementation of the Varroa Management Programme through maintenance of movement controls and surveillance programs provided New Zealand the time to develop and provide education and communication material to the beekeepers (Plant Health Australia 2013b).

Since the introduction of Varroa mite to the North Island almost all feral colonies and at least 20% of the managed colonies have disappeared (Mark et al.). Pollination costs have increased from an average of $80 per hive in 2001 to an average of $150 per hive in 2012 for example, onions $150, avocados $115 and Summerfruit $120 per hive (Ministry of Agriculture and Forestry 2001; Ministry for Primary Industries 2012). In the 2011/2012 years, treatments for Varroa mite ranged from $24-25 per hive, however these costs are expected to increase as resistance to treatments spreads (Ministry for Primary Industries 2012). Currently pollination requirements are still being met however the numbers of hives currently available are not predicted to be sufficient by 2015. If the predicted reductions in hive numbers due to Varroa mite and reduced honey prices eventuate, this situation will be more critical. It is estimated there is likely to be a shortfall of 72,950 hives nationally by 2015 (Simpson 2003).

Conclusion and Recommendations

The importance of Australia remaining free from Varroa mite has not only been economically proven [with an estimated benefit of $50.5 million per year (Cook et al. 2007)] but also shown through the response of growers through this census. Data collected clearly shows that the work of both managed and wild honey bees as pollinators is vital to pollination dependent industries and determines their overall sustainability. This in turn makes pollination dependent industries incredibly vulnerable to the effects of a Varroa mite incursion.

The location and availability of hives are not consistent or guaranteed as shown in the 2009 pollination report. The confidence that industries have on the availability of hives within their state, based on the previous season's hive availability, highlights an ongoing susceptibility to the potential impacts of Varroa mite. These industries run the risk of losing access to commercial hives during state or regional quarantine restrictions if the hives are located outside these borders due to location of nectar flows or to fulfill other pollination contracts.

Recommendation 1	Encourage floral and nectar resources

Pollination dependent industries can encourage the work of native bees, wild honey bees and other pollination insects by planting bee friendly crops/refuges that can provide valuable nectar and pollen sources throughout the year. This is especially important for crops that are considered less desirable to bees and need high density of populations to ensure adequate pollination.

Recommendation 2	Manage own hives

There is also the option of smaller growers owning and operating their own hives to help supplement their pollination needs. However, owning hives takes a lot of experience, is labour intensive and should not be undertaken lightly. If this approach was to be undertaken, it should be encouraged that growers contact their local department of agriculture apiary officer for more information.

Recommendation 3	Growers use specialised pollination contracts

Growers should aid in maintaining the biosecurity of honey bees through the use of specialised pollination contracts that require pollination providers to only supply pest and disease free honey bees. A pollination contract employs basic best management practices for both the grower and the beekeeper. Some specific clauses in the contract can require hives to be inspected before they enter a new property which will allow, in the event of a Varroa mite incursion, a traceable system of the health status of honey bees.

Recommendation 4	Chemical registration for Varroa mite chemical controls

Some of the key lessons gained from the New Zealand experience are the need to have chemicals (Miticides) readily available and registered in Australia to use in the eradication of Varroa mite through emergency use permits. By having a proven chemical already pre-registered an incursion response can be conducted rapidly without the need to spend time on registration paperwork. Shelf registration of Miticides should be encouraged.

Recommendation 5	Continue commitments to the National Bee Pest Surveillance Program

Australia currently undertakes a National Bee Pest Surveillance Program that includes the use of sentinel hives, floral sweep netting, hobby beekeepers and remote surveillance hives to monitor bee pests and pest bees at high risk ports of entry into Australia. Continuing with surveillance at key entry points into Australia will help in the early detection of Varroa mite which will increase the possibility of eradication. The earlier a new pest can be detected the greater the chance that it will be restricted to a limited area which may determine the technical feasibility of eradication.

Recommendation 6	Encourage compulsory beekeeper registration

The registration of beekeepers needs to become compulsory in every state and territory so that bee biosecurity can be monitored and in the event of a Varroa mite incursion, at risk hives can be quickly and efficiently located to help slow the spread of Varroa mite. Unlike New Zealand, the hives in Australia are every mobile which may increase the rate of Varroa spread in Australia once an incursion has taken place.

Recommendation 7	Increased R&D into pollination programs and alternative pollination techniques

Pollination dependent crop industries need to address the current gap in R&D work into alternative pollination techniques and selective breeding of crops to minimise reliance on pollination vectors. Options for investigation include increasing the use of native bees, investing in mechanical pollination techniques or selectively breeding for certain pollination traits. This will become particularly critical when the costs of pollination services increase and may become an unviable option for some growers.

Investment should also be increased into pollination programs that will aid in maintaining pollination services through resistance breeding of honey bees and alternative Varroa mite control methods. Increased preparedness for an incursion of Varroa mite will provide a mechanism for industry and growers to understand how they can maintain the growth and stability of production when the status of honey bees as readily available pollinators is destabilised.

Recommendation 8	Closer working relationship with the pollination dependent industries and the honey bee industry to include business planning and contingency planning

The impending threat of Varroa mite on the livelihoods of pollination dependent industries and beekeepers themselves is severe and will impact on the production of horticulture in Australia. Pollination dependent industries and beekeepers need to work together to mitigate the risk of Varroa mite entering the country and introduce contingency plans on how to maintain effective pollination if Varroa mite becomes established. Both beekeepers and growers of pollination dependent crops should undergo business management training to further understand what the increased costs of Varroa mite management would mean for their businesses, and how to absorb these costs into their business.

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Appendices

Appendix 1: Pollination Census: Peak Industry Body

1. Please indicate the peak industry body that you are representing:

Almond Board of Australia
Apple and Pear Australia Ltd
Avocados Australia Ltd
AUSVEG Limited
Canned Fruit Industry Council of Australia
Cherry Growers Australia Inc.
The Australian Prune Industry Association Inc.
Australia Melon Association Inc.
Summerfruit Australia Limited
Onions Australia

2. In which states and territories does your industry's production occur?

3. How would you describe the reliance of your industry on wild bees (European honey bees that are not managed by a beekeeper and live wild in the environment) for pollination services?

a) High (wild bees account for all pollination needs of the industry)
b) Medium (wild bees account for about half of the pollination needs of the industry)
c) Low (wild bees may account for a minor amount of pollination needs for the industry)
d) Unknown

Comments:

4. How would you describe the reliance of your industry on native bees (bee species found naturally in Australia, not of the *Apis* genera) for pollination services?

a) High (native bees account for all pollination needs of the industry)
b) Medium (native bees account for about half of the pollination need of the industry)
c) Low (native bees may account for a minor amount of pollination needs for the industry)
d) Unknown

Comments:

5. What proportion of pollination services employed by your industry is located in a different state to where production occurs?

a) 100% (all hired hives are located outside the state where production occurs)
b) 75%
c) 50%
d) 25%
e) None (all hired hives are located in the same state as production)

Comments:

6. If hives were restricted within state and territory borders, would your industry struggle to maintain access to existing levels of pollination services?

a) Yes b) No c) Unsure Comments:
7. Do you predict an increase in your industry's pollination requirements (e.g. from industry expansion)? Why?
8. Do you predict an increase in your industry's expenditure on pollination services in the next 5 years? Why?
9. In the event of a Varroa incursion where there is a major loss of wild bee colonies and managed hives, what alternative pollination techniques can your industry employ?
10. Does your industry fund any research into alternative pollination techniques?
11. What kind of information do you provide to growers on pollination options and alternatives to honey bee pollination?
12. What biosecurity practises does your industry request of hired pollination services to deter bee pest and diseases?
13. What level of impact would exotic pests of honey bees such as Varroa mite have on your industry's production? a) High (severe impact on production will occur) b) Medium (significant impact on production will occur) c) Low (minor impact on production will occur) d) Unknown (the potential impact is unknown) Comments:
14. Has your industry been involved in any specific Varroa incursion or pollination planning between growing regions? If yes, please specify.

Appendix 2: Pollination Census: Grower

1. What peak industry body best represents your crop? Almond Board of Australia Apple and Pear Australia Ltd Avocados Australia Ltd AUSVEG Limited Canned Fruit Industry Council of Australia Cherry Growers Australia Inc. The Australian Prune Industry Association Inc. Australia Melon Association Inc. Summerfruit Australia Limited Onions Australia
2. Please provide the following information about your farm: a) Postcode: b) Suburb/Town c) State d) Size (hectares) of each crop
3. How would you describe your reliance on wild bees (European honey bees that are not managed by a beekeeper and live wild in the environment) for pollination of your crops? a) High (wild bees account for all your pollination needs) b) Medium (wild bees account for about half of your pollination needs) c) Low (wild bees may account for a minor amount of your pollination needs) d) Unknown Comments:
4. How would you describe your reliance on native bees (bee species found naturally in Australia, not of the *Apis* genera) for pollination of your crops? a) High (native bees account for all your pollination) b) Medium (native bees account for about half of your pollination needs) c) Low (native bees may account for a minor amount of your pollination needs) d) Unknown Comments:
5. How would you describe your reliance on pollination services to pollinate your crops? a) High (100% all pollination comes from pollination services) b) Medium (around 50% of bee pollination comes from pollination services) c) Low (less then25% of bee pollination comes from pollination services) e) None (you employ no pollination services for your crops) Comments:
6. What stocking rate (per hectare) of hives do you use?
7. Where does your pollination service provide its hives from?

a) Within your region b) Within your state c) Out of state Comments:
8. What do you currently pay for pollination services (per hive) and do you expect an increase in this cost over the next 5 years? Why?
9. Will your pollination requirements increase (i.e. from increase in production area or increase in pollination dependent crops)? Why?
10. Do you manage any hives, if so how many?
11. If hives were restricted within state and territory borders, would you be able to pollinate your crops at existing levels?
12. In the event of a Varroa incursion where there is a major loss of wild bee colonies and managed hives, what alternative pollination techniques can you employ?
13. What level do you consider exotic pests of honey bees such as Varroa mite, a threat to your livelihood? a) High (threats to honey bees will have a direct and severe impact on my production) b) Medium (threats to honey bees will have a significant impact on my production) c) Low (threats to honey bees will have a minor effect on my production) d) None (threats to be honey bees will have no effect on my production) Comments:
14. What biosecurity practises do you request of hired pollination services to deter bee pest and diseases?

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