Submission No: 33
Date Received: 6/6/07
Secretary: [signature]

CSIRO

CSIRO Submission

The Future of the Australian Honey Bee Industry

May 2007

Enquiries should be addressed to:

Dr Paul De Barro

Stream Leader: Preparedness; Program Leader: Preparedness and Prevention, Cooperative Research Centre for National Plant Biosecurity

CSIRO Entomology

Contents

Executive Summary

Across Australia research capability in regards to the European honey bee *Apis mellifera* and the associated honey industry has declined markedly. The long term sustainability of the honey bee keeping industry requires that it adjusts to a model in which provision of pollinator services is the primary business. To do so will require not only a shift in the business practices of beekeepers, but also a recognition by the plant industries that depend on insect pollination that the use of managed pollination services provides an economic benefit that these industries should pay for.

Two key drivers, biosecurity and access to floral resources, directly threaten the long-term viability of the bee keeping industry. In the case of the former, exotic bee mites will eliminate feral bees and so create a demand for pollinator services. Similarly, the maintenance of strong hives able to deliver the pollinator service requires access to floral resources that can be used to build up hive strength.

It is also important to understand that benefits of pollination are felt not only in terms of volume of production. Efficient pollination can also have a strong influence on product quality, because many fruits grow larger and more symmetrically when well pollinated. Further, efficient pollination can shorten the time between flowering and harvest, creating savings in agricultural inputs. Pollination can also have significant impact on the animal production sector because of the importance of insect pollinated crops as fodder.

Australia has a wide range of agricultural industries that face damage in the event of declining honey bee populations.

By far the most serious threats to the viability of the Australian honey bee industry are introductions and establishments of exotic pests. The entry of these pests into Australia would have serious impacts on the honey bee industry and those rural industries that rely on honey bees for pollination. There are several real threats to honey bees in Australia and there is a high likelihood that within 10 years most feral honey bees and the service they provide could be lost. Unfortunately, the free pollination services by feral bees have been so reliable in the past that the vast majority of horticultural and agricultural industries have little or no recognition as to the importance of pollination and the implications that loss of *A. mellifera* would hold for their production systems. Current levels of preparedness are such that, should the health of feral honey bee colonies be affected, the consequences for key horticultural and agricultural industries would be severe.

Exotic invasions, particularly by the varroa mite (*Varroa destructor*) and the Asian bee mite (*Tropilaelaps* spp.), pose the greatest threat to insect crop pollination because of the impact they would have on feral *A. mellifera*. While the Asian bee (*Apis cerana*) poses a threat to pollination services overall, its impact is more likely to be environmental and so managed pollinator services are likely to be less affected.

The experience elsewhere in the world, including most recently in New Zealand, is that varroa very greatly diminishes the feral honey bee population to the point that they are virtually non-existent. Australian pollination dependent agricultural industries are likely to go from a position of having a high level of free feral honey bee pollination to a major pollination deficit if varroa becomes established. A major consequence of this risk is that the bee keeping industry will be asked to provide pollination services to substitute those that have been lost.

With the information currently available CSIRO has been able to demonstrate the substantial impact varroa is expected to have on the economy if it were to become a naturalised species, and through this the benefits of maintaining Australia's area free from this pest. In total, CSIRO estimates that these benefits would be between $21.3 million and $50.5 million per year if area freedom could be maintained, in other words, Australia could afford to spend this amount each year to exclude varroa and still be ahead. The results suggest that private beneficiaries of *V. destructor* exclusion are not only apiculturists, and that current cost sharing arrangements for incursion responses do not adequately reflect the spread of potential benefits.

Two of the main impacts of land management on the honey bee industry are the reduction in available native vegetation due to land clearing and the concurrent restriction of access to the remaining native vegetation for beekeepers.

There are three classes of impact that honey bees might cause: (a) competition with native species for floral resources; (b) changes in reproduction by native plants; and (c) competition with native species for nesting sites.

The key question for the future is to determine where and when the risk of negative impact is such that it is incompatible with nature conservation, and conversely where the impacts likely to be compatible with the designated land use.

Any R&D strategy should consider three avenues of attack. First is to preserve *A. mellifera* as an effective pollinator of Australian crops. Second is to maximise the benefits of *A. mellifera* by developing the approaches that will enable it to be managed so as to gain its peak effectiveness as a crop pollinator. Third, reduce reliance on *A. mellifera*, by determining how best to utilise the benefits from native Australian pollinators. To achieve these, a range of activities have been identified in the body of this submission to meet the biosecurity threats to the bee keeping industry.

Introduction

Across Australia research capability in regards to the European honey bee *Apis mellifera* and the associated honey industry has declined markedly. CSIRO has arguably the greatest concentration of researchers still involved in honey bee and pollination research. This submission draws on the expertise of Drs Denis Anderson (biosecurity threats), David Cook (economics of pollination), Saul Cunningham (ecology of crop pollination) and Dean Paini (impact of *A. mellifera* in native systems) and Paul De Barro (strategic threats to pollination services).

This inquiry examines the honey bee industry in terms of:

- Its current and future prospects.
- Its role in agriculture and forestry.
- Biosecurity issues.
- Trade issues.
- The impact of land management and bushfires.
- The research and development needs of the industry.
- Existing industry and Government work that has been undertaken for the honey bee industry.

CSIRO is well placed to contribute to the viability of the beekeeping industry through its strategic research on key issues including biosecurity directed research and pollination biology and ecology.

The current economic value of the Australia beekeeping industry, excluding pollination services, is around $60 million and with a further $60 million for paid pollination services[1]. However, the capacity to grow the value of the non-pollination aspects of the industry is limited and long term sustainability of the bee keeping industry requires that it adjusts to a model in which provision of pollinator services is the primary business *(Honeybee Industry Linkages Workshop - April 2007 RIRDC Publication No. 07/067)*. To do so will require not only a shift in the business practices of beekeepers, but also a recognition by the plant industries that depend on insect pollination that the use of managed pollination services provides an economic benefit that these industries should pay for. To date, apart from the almond industry, the level of acceptance of this premise would appear to be quite low primarily due to the heavy reliance on free pollination by feral honey bees. Without this market pull there will be considerable difficulties in maintaining an on going level of sustainability in the bee keeping industry.

Recent experiences in the USA and New Zealand in terms of varroa mite and colony collapse disorder provide good evidence that Australia's free pollination service is under threat and unlikely to continue at historical levels. Recent high profile events that threaten bees have led the plant industry peak bodies to start reviewing their vulnerability to the loss of free pollinator services. This provides an opportunity to beekeepers, but their ability to exploit this change in perceptions by plant industries is itself threatened by the very factors that are driving these industries to consider them in the first place, i.e. pest and disease threats to honey bees.

Two key drivers, biosecurity and access to floral resources, directly threaten the long term viability of the bee keeping industry. In the case of the former, exotic bee mites will eliminate feral bees and so create a demand for pollinator services. However the presence of the mites would also have a direct negative impact on the capacity of beekeepers to provide the services that would be in demand. Similarly, the maintenance of strong hives able to deliver the pollinator service requires access to floral resources that can be used to build up hive strength. Without these floral resources it will be difficult to maintain sufficient hives to meet demand. At present both these drivers are without clear solutions and require further research to provide solutions.

[1] Australian Honey Bee Industry Council http://www.honeybee.org.au/economics.htm#4

Its role in agriculture and forestry

Honey bees and crop pollination

Many crop plants require pollination if they are to produce seeds, fruits or nuts. For some plants pollination happens automatically within the flower, some require wind to move pollen (especially cereals such as wheat and rice) but many require flowers to be visited by insects. The degree to which crop production worldwide depends on insect pollination was the subject of a recent scientific study (Klein *et al.* 2007). This extensive review of the available data concluded that 76% of the major crop species worldwide benefit (in crop quantity or quality) from insect pollination. However, because many of the very high volume crops (e.g. cereal crops) do not benefit from insect pollination, the proportion of global crop production (in volume) that benefits from insect pollination is approximately 35%. In other words, loss of insect pollinators would dramatically affect the viability of diverse plant industries, and by extension the diversity of the human diet, but would have a lesser effect on the production of staple food products. Further, this study confirms that honey bees are the most frequently identified pollinating insect for most of these crops.

It is also important to understand that benefits of pollination are felt not only in terms of volume of production. Efficient pollination can also have a strong influence on product quality, because many fruits grow larger and more symmetrically when well pollinated. Further, efficient pollination can shorten the time between flowering and harvest, creating savings in agricultural inputs. One key input is water: shorter flowering resulting from efficient pollination can see a significant reduction in the need for irrigation. In these ways efficient pollination can be part of an overall management system that increases profits and improves market access.

Pollination can also have significant impact on the animal production sector because of the importance of insect pollinated crops as fodder. Legumes, such as clovers, are important as a source of protein for livestock, and many legumes benefit from insect pollination. Bee pollination can influence the persistence of clover in pasture, therefore affecting grazing quality. A study of agricultural industries in the south island of New Zealand found that the economic benefits of bee pollination were even greater in the pastoral industry than in horticulture (Simpson 2003).

The Klein *et al.* (2007) study provides a sense of the scale of the issue globally, but understanding the role of managed honey bees in Australia requires more specific knowledge on the Australian context. Australia produces only a subset of the global list of crops, and has its own distinct pollinators and beekeeping communities. Nevertheless, Australia has a wide range of agricultural industries that face damage in the event of declining honey bee populations (Cunningham *et al.* 2002). The degree of dependence on pollination varies by crop. At one end of the range is the almond industry. Almonds are entirely dependent on insect pollination, and the industry is expanding very rapidly in Australia. However, access to pollination services is already limiting its growth. At the other end of the scale, canola and cotton benefit from insect pollination, but do not depend on it. Few canola or cotton producers use any management strategies designed to improve pollination, but studies suggest that adoption of such approaches could be economically beneficial. Given the large size of the Australian canola and cotton crops, even a 10% benefit from pollination could be of great significance in whole-of-industry terms.

Observations of flower visitors in Australia confirm that the honey bee is the most frequent visitor to many crop species. Although some of these honey bees are from managed hives, many are in fact from the feral bee population and it is difficult to find anywhere in Australia where the insects visiting a flower are not predominantly honey bees. While there is little scientific data on the abundance of feral honey bees, there are very strong reasons to suggest that the feral honey bee service to crops is very high. Firstly, surveys of feral bee populations show that they can be extremely abundant in Australia (Oldroyd *et al.* 1997; Paton 1996). Secondly, surveys of agriculturalists find that very few pay for the provision of managed honey bees in their crops (Goodman and Hepworth 1996).

This high level of free feral honey bee pollination is at grave risk if *Varroa destructor* enters Australia. The experience elsewhere in the world, including most recently in New Zealand, is that *Varroa destructor* very greatly diminishes the feral honey bee population to the point that they are virtually non-existent. Australian pollination dependent agricultural industries are likely to go from a position of having a high level of free feral honey bee pollination to a major pollination deficit if *V. destructor* becomes established. This step change could occur quite quickly, given that *Varroa* has elsewhere shown the capacity to spread rapidly. A major consequence of this risk is that the bee keeping industry will be asked to provide pollination services to substitute those that have been lost. This is the chain of events that has been seen elsewhere in the world following the arrival of *Varroa*, most notably in the USA and New Zealand. What makes the Australian situation different is that it is widely thought that Australian agriculture is even more dependent on the at-risk feral honey bee pollination service and in this sense has even more to lose and less capacity to respond and mitigate the loss of feral bees.

Honey bees are not the only effective crop pollinators. Some crops are pollinated exclusively by insects other than honey bees, and for some crops it is known that other bee species are more effective than honey bees in terms of their effect on pollination. Most insect-pollinated crops are visited by a wide range of native insects, and studies have shown that for some crops species native insects are very effective pollinators. If the feral honey bee population was to decline, it is possible that native insects would compensate to some degree by continuing to provide a free pollination service to some crops. Unfortunately there is not enough data to be confident how effective this service would be. Nevertheless, an increasing number of studies from Australia and around the world show that native pollinators can provide a significant pollination service, and that this level of service is influenced by the habitat available for nesting and feeding. Maintaining these alternative native pollinators and determining how best to use them would provide a buffer for agricultural industries if the honey bee keepers cannot provide sufficient pollination services.

Biosecurity issues

Pollination in Australia

While much of the overseas insect crop pollination is managed, Australian farmers rely on feral honey bees for a considerable proportion of insect pollination of their crops. Most crops grown in Australia did not evolve with our native pollinators and so rely heavily on feral honey bees. In Australia, pollination by *A. mellifera* is mediated by:

- Free pollination provided by feral honey bees;
- Free pollination provided incidentally by hived honey bees owned by commercial and amateur beekeepers;
- Paid pollination services provided by commercial beekeepers

Threats to pollination services

By far the most serious threats to the viability of the Australian honey bee industry are introductions and establishments of exotic pests. The entry of these pests into Australia would have serious impacts on the honey bee industry and those rural industries that rely on honey bees for pollination.

There are several real threats to European honey bees in Australia and there is a high likelihood that within 10 years most feral honey bees and the service they provide could be lost. Unfortunately, the free pollination services by feral bees have been so reliable in the past that the vast majority of horticultural and agricultural industries have little or no recognition as to the importance of pollination and the implications that loss of *A. mellifera* would hold for their production systems. Current levels of preparedness are such that, should the health of feral honey bee colonies be affected, the consequences for key horticultural and agricultural industries would be severe.

Exotic invasions, particularly by the varroa mite (*Varroa destructor*) and the Asian bee mite (*Tropilaelaps* spp.), pose the greatest threat to insect crop pollination in Australia because of the impact they would have on managed and feral *A. mellifera*. While the Asian bee (*Apis cerana*) poses a threat to pollination services overall, its impact is more likely to be environmental and so managed pollinator services are likely to be less affected.

The varroa mite (*Varroa destructor*)

The varroa mite is considered the most serious global threat to beekeeping and is without question the most serious threat to the viability of the Australian honey bee industry. The mite is parasitic and feeds on the blood of adult and larval honey bees and reproduces on the bee brood. The mite also transmits viral and other pathogens, which rapidly kill entire bee colonies.

Varroa mite has been highly invasive around the world. It originated in the Japan – Korea region in 1950 and spread to Europe in the 1970s. In 1987, it turned up in the USA and in 1990 in South America followed by Africa in 1997 and New Zealand in 2000. The only agricultural regions in the world free of Varroa mite are Australia and PNG. Varroa is, however, in Indonesia. In countries where Varroa mite is established, feral honey bees have been largely wiped out. In New Zealand feral bees virtually vanished from the North island within four years of the invasion.

Australia is one of the few remaining regions in the world still free of this destructive mite. Since switching from its primary host, the Asian honey bee (*Apis cerana*) some 50-60 years ago, the mite has spread around the world. It entered New Zealand in 2000 and is also now threateningly close to Australia in east Indonesia. In all regions where the mite has become established hived honey bee colonies have been reduced by about 25%, feral honey bees have been eliminated and managed pollination services severely damaged and unable to meet the demand for pollination services. No better is this exemplified than in the USA where the mite first entered in 1987. Since its arrival and establishment:

- The feral bee population has been diminished to the point where it no longer a common pollinator;
- Managed colonies have been reduced by about 30% and cost of maintaining hives has increased by 25%;
- Many beekeepers have left the industry and those remaining have been forced to use acaricides;
- The honey bee population has suffered a pronounced loss of genetic variation. Selection of stock from a few 'varroa tolerant' colonies has exacerbated the problem;
- Crop growers have been forced to look elsewhere for their pollinators, including importing Australian honey bees.
- Innovation and development within the honey bee industry has been stifled because of redirected resources (particularly research effort) to counter the mite.
- Sustainable management of Varroa in managed hives is difficult as the mite rapidly develops resistance to miticides used in hives to control varroa.
- The decline in the total number of available managed hives along with an increasing demand for hives by agricultural and horticultural producers has seen a 4-5 fold increase in the cost of hives and an annually increasing gap between demand for hives and the capacity to supply them.

This last point is perhaps the most critical in regards to identifying Australia's vulnerability. The heavy reliance on feral honey bees has meant there has been a reduced demand for managed hives and, as a consequence, the managed pollination industry, by international standards is quite small and under developed. Given that the more numerous and sophisticated providers of managed hives in the USA and New Zealand have failed to keep pace with demand it is probable that those in Australia will be even less able. As a consequence the economic/market shock is likely to be greater and last longer.

The arrival of varroa in the US and New Zealand has made crop growers and the general public more appreciative of the role of honey bees in pollination. Growers now accept the value of honey bees and are now prepared to pay for pollination services based on the value that the bees add to crops. As well, the package and queen bee segments of the honey bee industry have been boosted.

The threat of a varroa mite incursion into Australia is real. Any European honey bee swarm arriving on a vessel at an Australian port is likely to be carrying the mite. The regular arrivals of Asian honey bees on ship at Australian ports, as now witnessed at Cairns in North Queensland, also present a threat of introducing the mite, but this risk is much less than for swarms of European honey bees. It should be noted that the mite managed to slip through New Zealand's quarantine defences, which are similar to Australia. Hence, while every effort must be made to prevent an incursion, there must also be a strategy to combat the pest in the event of an incursion occurring.

Potential economic impact of varroa (based on Cook *et al.* in press)

If the worst does indeed occur and the *V. destructor* mite becomes established on the Australian mainland, what might the costs of spread and eventual naturalisation over time be? Naturalisation is complete when a species spreads to its full capacity within an environment, such that descendents of the original specimens introduced into that environment become permanent, non-spreading members of the floral/fauna (Mack, 1996, Mack and Lonsdale, 2001). By making simple predictions about the behaviour of producers who rely on wild honey bee pollinators, and what behavioural change is likely to cost a 'rough estimate' of the anticipated cost is provided.

Expressing results as an annual average, CSIRO estimates that the process of V. destructor naturalisation would cost Australian plant industries between $21.3 million and $50.5 million per year over the next thirty years if no response were mounted after an incursion. This analysis focuses specifically on the costs not the value of losses directly attributable to varroa, taking into account the expected spread of the mite over time. It is important to note that this analysis is not attempting to put a figure specifically on the total value of production by crops pollinated by honey bees, but rather that it is estimating the amount that could be afforded to be spent each year in keeping varroa out of Australia. In this, the analysis departs from methods used in past assessments for this species in the Australian context, e.g., Gill (1989) and Gordon and Davis (2003). Those methods placed a value on honey bee pollination services and assumed an immediate 100% loss of those services in the presence of varroa; stated that the total value of crops pollinated by honey bees is worth $2 billion, which has the tendency to imply that once varroa gets in, all pollination by honey bees will cease immediately and that there will be no capacity to mitigate these losses.

Of the 25 crops that were used to simulate *V. destructor* impact, the largest benefits are enjoyed by the sunflower industry, followed by the avocado, strawberry and apple industries. As Figure 1 demonstrates, 13 crops derived notional benefits from *V. destructor*-freedom of over $1 million per year. Technical model limitations prevented the inclusion of other crops and pastures, but the implication is nevertheless clear.

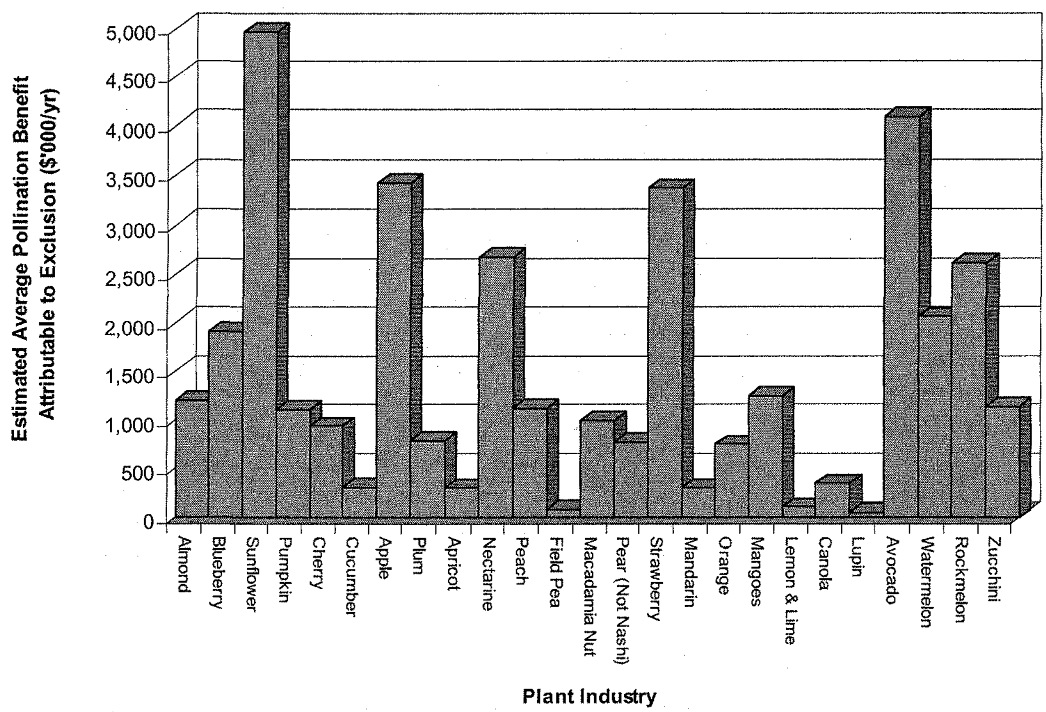

Figure 2 Estimated benefits to selected Australian plant industries

Estimating the parameter values in a model of this type is difficult due to a lack of information on parameter values. In terms of biological parameters, our model is particularly sensitive to changes in the intrinsic rate of population growth and rate of satellite site generation. The economic parameter with the highest sensitivity is the discount rate. The higher the discount rate, the lower the present value of future impacts, and therefore the lower the economic significance of *V. destructor* in terms of avoided economic impacts by maintaining exclusion after 30 years.

Yield losses expected in the absence of feral *A. mellifera* (i.e. if *V. destructor* exclusion is unsuccessful) is also a highly sensitive parameter. The current lack of information available to accurately predict the pollination contribution made by feral hives emphasises the need for further research in this area. If CSIRO has been too conservative in estimating, expected losses will be larger than indicated by our results. Interestingly, changes in the cost per hive have a lesser impact on results. This indicates that a price rise driven by a negative supply shock and a positive demand shock in the market for pollination services may not have implications as severe as proportional changes in other variables (such a yield effects) on the scale of the overall impact of a *V. destructor* naturalisation. But if the induced price rise is very large it may have severe implications.

The high sensitivity of results to changes in the intrinsic rate of *V. destructor* population growth indicates that the likely returns to investment in spread mitigation and containment technologies may be very high. If an outbreak were to occur, the damage inflicted by the pest could be substantially reduced even in the control case of negligible government assistance. The results suggest that if the inter-hive spread can be reduced by a factor of 20 per cent, for example, the overall expected damage may fall by almost 25 per cent (assuming direct proportionality). Physically controlling this parameter will be far from easy given the observed "robbing" that occurs periodically between competing *A. mellifera* colonies, and research into mitigating this behaviour is likely to be complex. Nevertheless, there may be substantial pay-offs in terms of reduced expected damage costs in the long term.

Because they are treated separately in the model, changes in the probabilities of entry and establishment produce smaller changes in the results than perhaps one might have expected. But, while the individual parameter sensitivities are relatively low, results can be seen to alter to a greater extent when scenarios involving more than one parameter change are considered. For instance, a change in climatic conditions (i.e. global warming) may have implications for several parameters over time. It is not known what implications global warming has for *V. destructor* establishment and growth around the world, but let us speculate to demonstrate how this could be captured in the model. Given the mite is believed to have evolved in the tropics, the probability of establishment following introduction in Australia may rise as conditions become warmer. Let us assume it does so by around 20 per cent. The rate of growth of the population may also increase once establishment takes place since conditions are more favourable to the mite, as could the rate of satellite generation. Assume both of these parameters increase by around 20 per cent. Running such a scenario through the model produces an estimated mean average annual loss of producer surplus of around $46.8 million, representing a rise in the biosecurity significance of *V. destructor* by around 28 per cent.

Given the high sensitivity of results to both the discount rate and the intrinsic rate of population growth, the expected impact of the pest depends on the time over which it is simulated. Figure 2 plots cumulative average annual expected benefits from maintaining *V. destructor* freedom from the present to 30 years into the future. The sigmoid pattern of spread (and subsequent impact) observed in the plots for the mean value and the 5 and 95 per cent confidence intervals are due to the spread model used in the model. The expected damage avoided increases at an increasing rate until around the fifteenth time period. Thereafter it increases at a decreasing rate up until year 30. By year 20, where the mean expected benefit is $23.4 million, the variance associated with our estimate is high in line with the variability in parameter estimates. This uncertainty about the mean increases with the period over which the simulation is run.

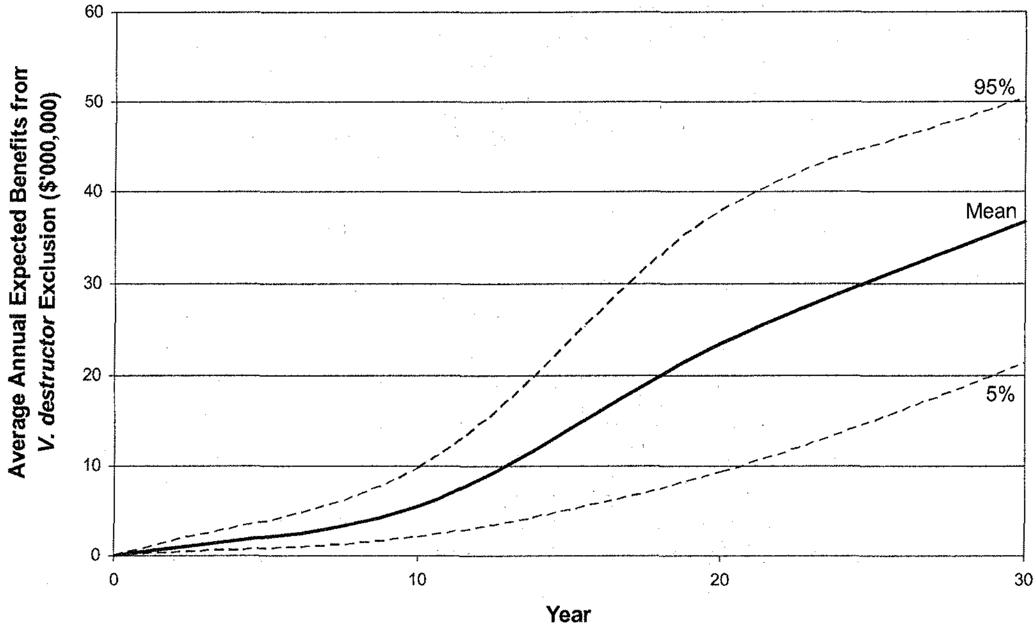

Figure 2 Average annual expected damage from *Varroa destructor* over time

Two other points in regards to Figure 2 should also be emphasised. Firstly, these are 'expected' benefits of exclusion over time, and are not projected damages from an incursion at time 0. Secondly, all time periods after time zero have a positive expected benefit of exclusion, reflecting the fact that the probability of entry and establishment is always greater than zero. Hence, the significance of the pest from a biosecurity perspective depends greatly on the time period over which the assessment is made.

Cost sharing arrangements

Australia has developed a reputation for innovative invasive species policy making, particularly in relation to response arrangements for exotic organisms posing significant threats to agriculture and the environment. An important part of the current incursion response arrangements are the agreement of eradication cost sharing between industry and the State and Federal governments, as in the case of the Emergency Animal Disease Response Agreement (Animal Health Australia, 2002) and the Emergency Plant Pest Response Deed (Plant Health Australia, 2004). The basis of these agreements is that in the event of an incursion by a species covered in the arrangements, a pre-agreed cost sharing arrangement for eradication is activated. This aids in the early reporting of an incursion, minimises the response time and provides the opportunity to minimise the size and impact of an alien invasive species incursion.

The guiding principle of cost sharing agreements is 'user (or beneficiary) pays', so it is very important that beneficiaries be clearly defined. By ensuring that those parties who stand to benefit most from the elimination of an invasive species outbreak contribute an appropriate amount, governments and industry can ensure a socially desirable level of eradication is delivered. If a pest has a broader impact than anticipated and there are affected industries that are not signatories to a cost sharing agreement, an incursion response may not deliver an adequate (or socially desirable) level of service provision, or be prematurely terminated. If an eradication campaign is successful despite these circumstance applying, non-signatory beneficiaries will become "free riders" on the eradication services.

The existing cost sharing structures in response to an incursion of varroa mite do not reflect the reality of the costs of an incursion. There is an 80:20 government:industry split where "industry" is the bee keeping industry and the plant production sector is not considered. This is further complicated by the issue of "consequential loss". In fact, the economic impact of varroa on bee keepers will be far less than the impact on producers of bee pollinated crops. Currently, the apiary industry has less than $300,000 that it could contribute to an incursion response. This means that if an incursion occurred today there would only be around $1 million available for a response campaign.

If the mite were to become established in Australia, control techniques are available for the apiculture industry to minimise its impact on commercial hived colonies. However, the impact on the large wild (or feral) *A. mellifera* population would almost certainly be severe (Watanabe, 1994), as would the flow-on effects to plant industries that rely on feral bees for pollination. Under current cost sharing arrangements these benefits are not recognised. An incursion of *V. destructor* would be covered under the Emergency Animal Disease Response Agreement. Plant industries that depend on pollination are not signatories to this agreement and hence would not be included in the funding arrangements.

Conclusion

With the information currently available CSIRO has been able to demonstrate the substantial impact *V. destructor* is expected to have on the economy if it were to become a naturalised species, and through this the benefits of maintaining Australia's area free from this pest. The expected benefits to 25 plant industries of remaining free from the pest over the next 30 years have been estimated using a stochastic impact simulation model. In total, CSIRO estimates that these benefits would be between $21.3 million and $50.5 million per year if area freedom could be maintained. This benefit is not reflected in current incursion response cost sharing arrangements. This analysis is also based only on 25 plant industries. The magnitude of the benefit will therefore increase should all plant industries with some reliance on *A. mellifera* be included.

The results suggest that private beneficiaries of *V. destructor* exclusion are not only apiculturists, and that current cost sharing arrangements for incursion responses do not adequately reflect the spread of potential benefits. The substantial expected benefits of *V. destructor* exclusion estimated suggest that perhaps this pest should be included in the EPPRD (Emergency Plant Pest Response Deed) rather than the EADRA (Emergency Animal Disease Response Deed).

The Asian bee mite (*Tropilaelaps* spp.)

The Asian bee mite is regarded as the second most important threat to the viability of the Australian honey bee industry. While the mite is actually more damaging to honey bees than the varroa mite, its risk of entry into Australia is less. Like the varroa mite, the Asian bee mite is a parasite that feeds on the blood of bee larvae and reproduces on bee brood.

The primary host of the Asian bee mite is the giant honey bee (*Apis dorsata*), that is found throughout Asia. Swarms of this bee have been intercepted in the past at Australian ports. The mite is also now on our doorstep in the western regions of New Guinea, after it was introduced there by Indonesians on infested European honey bee colonies imported from Java. Attempt to eradicate it from New Guinea during the mid 1990's failed.

The impact of the Asian bee mite establishing in Australia will be similar to that of the varroa mite, but worse, as the Asian bee mite is able to multiply and kill European honey bee colonies much faster than the varroa mite.

The Asian honey bee (*Apis cerana*)

The Asian honey bee is the primary host of many different kinds of varroa mites. However, only populations from the Korea-Japan region carry the damaging forms of *Varroa destructor*. Other populations carry mites that are harmless to European honey bees.

The Asian honey bee has become an invasive pest in the New Guinea-Pacific since it was introduced into New Guinea in the late 1970's. It is now present throughout New Guinea and on offshore islands and in 2003 was found to be well established in the eastern Solomon Islands, 1300km from New Guinea. The bee almost certainly arrived in the Solomon Islands on a shipping vessel from New Guinea. Since its arrival in the Solomon Islands the local honey bee population and honey production have fallen sharply.

The establishment of the Asian honey bee in Australia would have a serious impact on Australian beekeepers. In Papua New Guinea and the Solomon Islands the bee has reduced hived European honey bee colonies through its aggressive foraging and robbing behaviour. Male Asian honey bees can also mate with European honey bee queens and reduce hive productivity. The bee has also become a major pest around cities and towns and, because it can nest in cavities much smaller than needed by swarms of the European honey bee, it has environmental concerns.

The present incursion of the Asian honey bee at Cairns, together with almost annual arrivals of the bee at Australian ports since the late 1990's, shows just how real the risk of invasion by this bee is.

Colony Collapse Disorder of honey bees in the United States

Colony collapse disorder, or CCD, is a recent disorder of US honey bees. It was first reported in late 2006-early 2007 and, since then, it has been estimated to have wiped out up to a quarter of the US honey bee population. The disorder is characterized by the sudden disappearance of the worker bee population from a single bee colony followed by rapid collapse and death of the colony. The cause is not yet known, and several suspected causes are currently being investigated, including environmental stresses, malnutrition, unknown pathogens, mites, pesticides, emissions from cellular phones and genetically modified crops. There is no doubt that the impact of CCD on managed hives is quite severe, however to date the etiology remains undetermined and as a consequence it is not possible to assess the level of threat posed to the bee keeping industry in Australia.

Other exotic threats

The tracheal mite (*Acarapis woodi*)

This small parasitic mite was first discovered in honey bees in the United Kingdom in 1921 and then in the US in 1984. The mite is now present on every continent except Australia (it is also not yet present in New Zealand). The mite lives in the breathing airways (tracheae) of adult bees where it feeds on the bee blood. Individual bees die because of the disruption to their respiration and from micro-organisms that enter their blood through the damaged airways. High infestations reduce the life spans of bees and lead to the death of entire bee colonies.

If the tracheal mite arrives in Australia it will cause economic hardship for beekeepers, and they will have to use acaricides to control it. The most likely route of entry of this mite into Australia is on swarms of European and Asia honey bee arriving at vessel at sea ports.

Exotic species of honey bees

The giant Asian honey bee (*Apis dorsata*) which is the native host of the *Tropilaelaps* mite as well as Africanized (killer) European honey bees (*Apis mellifera scutillata*) are further threats to the Australian honey bee industry. Swarms of both these species of bee have been previously intercepted at Australian ports.

The impact of land management and bushfires

Two of the main impacts of land management on the honey bee industry are the reduction in available native vegetation due to land clearing and the concurrent restriction of access to the remaining native vegetation for beekeepers. While land clearing has slowed in recent years, beekeepers indicate that diminished access to native vegetation is an on-going issue. This diminished access occurs because honey bees are an introduced species that interacts with native species, creating issues of concern in biodiversity conservation. The relevant government agencies have responded to this risk by considering honey bee impacts in land management plans and in the case of NSW, listing competition between feral honey bees and native wildlife as a threatening process under the NSW Threatened Species Conservation Act (P. Gibbons, pers. comm.).

Scientifically demonstrating that an introduced animal has significant effects on native species is always a difficult challenge, consequently the amount of research-based information is limited. There are three classes of impact that honey bees might cause:

Competition with native species for floral resources

There have been numerous studies from around the world showing that when honey bees are present, native bee visitation rates are reduced. Unfortunately, this research does not answer the fundamental question regarding the long term survival of these native species in response to honey bee competition.

Only by looking at reproduction, survival, or population levels can one really answer this question. Recently researchers have focused on the reproduction of native bees when honey bees are present. Two studies, one of which was conducted in Australia, show a negative impact of honey bees on natives (Paini and Roberts 2005; Thomson 2004), and two others found no impact (Paini *et al.* 2005; Spessa 1999).

Honey bees might also compete with large animals, such as nectar-feeding birds. Paton (1993) showed that honeyeater feeding behaviour is affected by the presence of honey bees, such that birds travelled further to collect nectar. To our knowledge no researcher has investigated the impact of honey bees on native marsupial pollinators.

Changes in reproduction by native plants

Honey bees have distinctive behaviours that mean they may cause patterns of plant pollination that differ from the native pollinators. Studies of different plant species have shown different kinds of effects, with honey bees diminishing pollination of some species and enhancing pollination of others (Gross & Mackay 1998). Honey bee pollination can also affect patterns of gene flow, such that their pollination increases the frequency of mating over short distances rather than long distances (England *et al.* 2001) which could lead to inbreeding effects.

Competition with native species for nesting sites

It has been shown that bees select similar hollows to some endangered species (Oldroyd *et al.* 1994), and some endangered vertebrates are limited by the availability of hollows (Lindenmayer *et al.* 2002). There have been two cases reported where nests of the white-tailed cockatoo failed as a result of swarming honey bees (Saunders 1979). Honey bees are also known to occupy caves, where they could affect roosting of bat species.

Whereas affects on plant reproduction and competition for floral resources might occur with managed or feral bees, competition for nesting sites is exclusively linked to feral honey bees. From a management point of view, bees in commercial hives can be withdrawn if problems arise. The feral population, however, is more or less entrenched. While feral honey bees obviously derive from the domestic managed population, there is very little data available to show whether the managed bee population continues to support the feral populations. It might be that placing bee hives in native vegetation significantly increases the size and stability of the feral bee population, but more research is needed on this matter.

The scientific literature shows that negative biodiversity impacts of honey bees have been documented in some cases. In addition, it shows that negative effects will not be felt in all sites at all times. Indeed some studies suggest that in some times, particularly when nectar is very abundant, competition with native fauna is low (Paton 1999). In other words it is false to suggest honey bees will never have negative effects on nature conservation, just as it is false to suggest that they will have serious negative impacts in all circumstances. The key question for the future is to determine where and when the risk of negative impact is such that it is incompatible with nature conservation, and conversely where the impacts likely to be compatible with the designated land use.

The research and development needs of the industry

Any R&D strategy should consider three avenues of attack. First is to preserve *A. mellifera* as an effective pollinator of Australian crops. Second is to maximise the benefits of *A. mellifera* by developing the approaches that will enable it to be managed so as to gain its peak effectiveness as a crop pollinator. Third, reduce reliance on *A. mellifera*, by determining how best to utilise the benefits from native Australian pollinators. To achieve these a range of activities could be considered to meet the biosecurity threats to the bee keeping industry.

1. In terms of probability of entry, current evidence suggests that varroa mite poses the greatest threat. As a consequence now is the time to consider research aimed at developing contingency strategies for controlling varroa. A critical issue is the current susceptibility of *A. mellifera* to varroa mite and a key to addressing this is to understand the mechanism which has enabled *V. destructor* to shift onto worker brood and thereby identify mechanisms for resistance. This knowledge, combined

with our knowledge of the honey bee genome offers the prospect of identifying the genetic basis for resistance and developing the capacity to breed bees resistant to the mite thereby reducing the need for miticides and increasing the level of sustainability of hive management.

2. Understanding of the return on investment and marginal benefits associated with a range of strategies and approaches aimed at risk minimization for biosecurity threats. A range of different strategies and approaches are available; apportioning R&D investment involves making decisions in regards to return on investment. Choosing between different strategies needs to be viewed in terms of net value of the gains vs. the cost of the investment and the ongoing cost of the strategy. Such an approach would provide a sound basis upon which to prioritise R&D investment.

3. Developing pollination strategies for particular crops under Australia conditions. To what extent do different crops of significance currently rely on the free feral honey bee service? Such information would provide the basis for the development of a strategy aimed at developing the relationship between plant industries at risk from the loss of pollination services through the loss of feral bees and the providers of a managed pollination service. Central to this will be the knowledge of how best to use bees to provide managed pollination of a range of crops in Australia where this does not yet take place to any great extent.

4. Improved diagnostics for bee pests and diseases (some Australian queen producers would like to import US bees and export their offspring back to the US but can't do this at present due to poor diagnostics for Africanized bees).

5. A key issue confronting beekeepers is the environmental concern around the perceived impact of honey bees on native flora and fauna and weeds. However, the knowledge upon which this is based has been drawn from a narrow range where vested interests have exposed the process to accusations of framing, context dependence and motivational bias. This opens the area to bias and misleading prioritisation. A key set of questions needs to be answered before issues such as access to floral resources can be dealt with effectively. These questions include, what are the population dynamics of the feral honey bee population? How much will varroa change this? To what degree are feral populations dependent on the managed populations for re-colonization? What plant communities and animal species are most vulnerable to negative effects of feral honey bees?

6. At present the bee keeping industry is primarily focused on *A. mellifera*. In addition, there has been some interest from the lucerne industry in leafcutter bees, but this is well short of becoming a sustainable industry. To reduce reliance on *A. mellifera*, and to broaden the product base for beekeepers, native pollinators that may be directly managed for crop pollination benefits should be considered. At present our knowledge in this regard is patchy and insufficient to provide a clear picture of the potential role of native species.

References

Anderson DL & Trueman JWH (2000) Varroa jacobsoni (Acari: Varroidae) is more than one species. Experimental and Applied Acarology, 24, 165-189.

Animal Health Australia (2002) Government and Livestock Industry Cost Sharing Deed in Respect of Emergency Animal Disease Response. Canberra, Animal Health Australia.

Cook DC, Thomas MB, Cunningham SA, Anderson DL & De Barro PJ (in press) Predicting the economic impact of an invasive species on an ecosystem service. Ecological Applications

Cunningham SA, FitzGibbon F, Heard TA (2002) The future of pollinators for Australian Agriculture. Australian Journal of Agricultural Research 53:893-900

England PR, Beynon F, Ayre DJ, Whelan RJ (2001) A Molecular Genetic Assessment of Mating-System Variation in a Naturally Bird-Pollinated Shrub: Contributions From Birds and Introduced Honey bees. *Conservation Biology 15, 1645-1655.*

Goodman RD, Hepworth G (1996) A survey of feral and managed honey bee colonies in the Goulburn Valley, Victoria. A report to the Horticultural Research and Development Corporation. Institute for Horticultural Development, Victoria.

Gross C. L. (2001) The effect of introduced honey bees on native bee visitation and fruit-set in Dillwynia juniperina (Fabaceae) in a fragmented ecosystem. Biological Conservation 102, 89-95.

Gross CL, Mackay D (1998) Honey bees reduce fitness in the pioneer shrub Melastome affine (Melastomataceae). Biological Conservation 86, 169-178.

Klein A-M, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society of London, B. 274:303-313

Lindenmayer DB, MacGregor C & Gibbons P (2002) Comment - Economics of a nest-box program for the conservation of an endangered species: a re-appraisal. Canadian Journal of Forest Research 32, 2244-2247.

Mack R & Lonsdale W (2001) Humans as global plant dispersers: getting more than we bargained for. Bioscience, 51, 95-102.

Mack RN (1996) Predicting the identity and fate of plant invaders: emergent and emerging approaches. Biological Conservation, 78, 107-121.

Oldroyd BP, Lawler SH, Crozier RH (1994) Do Feral Honey-Bees (Apis mellifera) and Regent Parrots (Polytelis anthopeplus) Compete for Nest Sites. Australian Journal of Ecology 19, 444-450

Oldroyd BP, Thexton EG, Lawler SH, Crozier RH (1997) Population demography of Australian feral bees (Apis mellifera). Oecologia 111:381-387

Paini DR. & Roberts JD (2005) Commercial honey bees (Apis mellifera) reduce the fecundity of an Australian native bee (Hylaeus alcyoneus). Biological Conservation 123, 103-12.

Paini DR,Williams MR & Roberts JD (2005) No short-term impact of honey bees on the reproductive success of an Australian native bee. Apidologie 36, 613-21.

Paton DC (1993) Honey bees in the Australian environment. BioScience 43, 95-103.

Paton DC (1996) Overview of the impacts of managed and feral honey bees in Australia. Canberra, Australian Nature Conservation Agency.

Paton DC (1999) Impact of commercial honey bees on flora and fauna in Ngarkat conservation park. Rural Industries Research and Development Corporation.

Plant Health Australia (2004) PLANTPLAN: Australian Emergency Plant Pest Response Plan, Canberra, Plant Health Australia.

Saunders DA (1979) The availability of tree hollows for use as nest sites by White-tailed Black Cockatoos. Australian Wildlife Research 6, 205-16.

Simpson B (2003) Summary of assessments of the economic impact of Varroa in the south island of New Zealand. http://search.maf.govt.nz/bio/search.aln?search=cost+benefit+varroa&other=opt%3Aand

Spessa (1999) Behavioural and population ecology of an Australian native bee, Amphylaeus morosus (Colletidae: Hylaeinae). Australian National University. PhD Thesis, Canberra.

Thomson D (2004) Competitive interactions between the invasive European honey bee and native bumble bees. Ecology 85, 458-70.

Watanabe ME (1994) Pollination worries rise as honey bees decline. Science, 265, 1170.