Final Report

Loss of horticultural pollination services from wild insects following bushfires

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Delivery partner:

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Project code:

PH20002

Project:

Loss of horticultural pollination services from wild insects following bushfires (PH20002)

Disclaimer:

Funding statement:

Loss of horticultural pollination services from wild insects following bushfires (PH20002) is funded through the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from Western Sydney University and contributions from the Australian Government.

Publishing details:

Published and distributed by: Hort Innovation

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Contents

Public summary

The overall aim of this project was to conduct a case study of the impact of an extreme event (major bushfire) on wild pollinator communities and the pollination services they provide to a focal horticultural crop (apple).

Extreme events, such as bushfires and floods, are increasing in frequency with climate change, but little is known about impacts on crop pollination. In a previous project (PH15001), we studied apple pollination for 3 years in the Bilpin (NSW) region. The landscape was burnt extensively during the Black Summer (2019/20) bushfires, providing an opportunity to study how the event affected pollinators, landscape floral resources and crop pollination, using the same methods and sites as in PH15001. In addition, since honeybees are the main pollinators of apples in Australia, we tested a "mark and recapture" method to estimate the contribution of wild honeybees to orchard pollination, since wild honeybee populations are likely to decrease severely if Varroa spreads to this region, as now seems very likely.

We aimed to survey landscape floral resources every 6-8 weeks throughout the year and conduct on-crop pollinator surveys and honeybee marking each crop flowering season (2020-2022). However, due to COVID travel restrictions (2021) and Varroa hive movement restrictions (2022), we only conducted marking in 2020, and on-crop surveys in 2020 and 2022. In contrast, landscape floral resources surveys were only minimally impacted.

Overall, we found substantial changes in the plant species providing floral resources to pollinators in the burnt landscape around the farms, but little change in the non-crop (mostly weedy species) plants on farms. We also saw a decrease in the number of flower visits by honey and stingless bees (some measures) and an increase in visits by flies (all measures). However, the total crop visitation by the two main pollinators (honey and stingless bees), which account for almost 90% of all visits, was within the range of what we saw across seasons before the fire event. A dramatic result in 2022 was an almost complete absence of stingless bees from apple flowers, but this is well explained by the unusually cool, wet weather under La Nina conditions.

In our marking experiment, about 50% of honeybees visiting the crop were not from hives on the farm, so either from wild colonies or distant managed hives. Interestingly, we also recorded marked bees from one farm visiting the same crop on other farms up to 1.5 km away. This case study provides a fairly simple way to quantify the contribution of managed on-farm hives versus wild honeybees and has potential use in other cropping scenarios. It also suggests that if Varroa substantially reduces wild honeybee colonies, as now expected, Bilpin orchards may suffer considerable loss of important "free" pollination services from wild honeybees. Other regions and crops that rely significantly on pollination by wild honeybees will also face this challenge.

Keywords

Apple, pollination, honey bee, Varroa, extreme events, climate change, bushfire, floral resources

Introduction

Extreme events such as bushfires, droughts and floods are important features of the Australian environment and predicted to increase in frequency with climate change (Dey et al. 2020; Nolan et al. 2020; Perkins-Kirkpatrick et al. 2020). However, there has been very little research on how such events affect pollination services to horticulture, and none that we are aware of in Australia. In general, extreme events can cause major losses of both pollinating insects and floral resources (Erenier et al. 2020; Nicholson and Egan 2020), but these losses could be either short or long-term so research is needed to measure the extent and nature of losses and how quickly they can recover (Erenier et al. 2020). To address these issues rigorously, it is important to measure pollination services before an event occurs in order to quantify changes and potentially attribute them to the extreme event.

This is rarely possible, because extreme events are unlikely to happen in the few sites where someone has been studying crop pollination services recently (Erenier et al. 2020). Such opportunities are therefore valuable case studies and one arose recently following major bushfires in the Bilpin apple-growing region (NSW), where we conducted apple pollination research for the three years preceding the bushfires (PH15001 'Healthy bee populations for sustainable pollination in horticulture').

The widespread devastation of the 2019/2020 "Black Summer" fire season is unprecedented but may be a harbinger of the "new normal" as climate change progresses (Nolan et al. 2020). The bushfires caused substantial losses to growers in several areas of Australia. In particular, apple orchards have been impacted in many areas, including Batlow, Bilpin, Adelaide Hills and Stanthorpe. In some cases, orchards have burnt with loss of many fruit-bearing trees. In other cases, firefighters limited direct damage to the orchards, but surrounding bush areas have been severely burnt. This will have killed millions of wild pollinators, including wild honey bees and native bees (Erenier et al. 2020; Saunders et al. 2021).

Pollination in orchards involves both managed honey bees and a variety of wild insects (Rader et al 2015). Although many growers rent honey bee hives, we do not know how much they contribute relative to the "incidental pollination" provided by wild insects (Rader et al 2015). While some wild insects may nest in orchards, most wild bees visit orchards from surrounding bushland, so despite little direct damage to orchards, burning of surrounding bush could have major effects on wild insect pollination services to them.

Thanks to research carried out for PH15001, a unique opportunity arose to evaluate the impact of bushfires on pollination in apple orchards in Bilpin. This is because for the three years (2017-2019) before the extreme event, we made systematic surveys of: (1) insect pollinators visiting apple flowers on orchards, (2) other floral resources on orchards and in study plots in the surrounding bush, and (3) the pollinators visiting and using these non-crop floral resources throughout the year. Consequently, we conducted a follow-up "post-fire" project using the same methodology in the same sites to uncover both immediate changes and the extent to which the flora and wild pollinator populations change in the following seasons.

Our previous work under PH15001 has emphasized how apple pollination in Australia relies heavily on honey bees (Tierney et al. 2023). In this context, it is important to understand how much wild honey bees (as opposed to on-farm hives) contribute to crop pollination, since when Varroa invades a wild honeybee population >90% hives may perish. If bushfires have significantly reduced wild honey bee numbers around orchards, we may gain a good idea of their relative contribution to orchard pollination and therefore the level of threat posed by a Varroa invasion. To further this are of investigation, we also planned to conduct an experiment in which all bees from on-farm hives were marked, allowing us to count relative numbers of hive and wild honey bees visiting the crop.

Methodology

This project builds on our research on crop pollinators and floral resources under PH15001. The unique opportunity is provided by having three years of field data from before the bushfires and thus the ability to obtain follow-on data from the same sites in Bilpin after bushfires ravaged the area in 2019/20. It is crucial to use the same methods to extend these datasets, allowing rigorous comparisons of the situation before and after the fires, so we continued to use the methodologies employed by Dr Amy Gilpin (floral resources) and Dr Simon Tierney (crop pollinators) in PH15001. A more detailed technical presentation of methods is provided in Appendices 1 (floral resources) and 2 (crop pollinators).

Vegetation around Bilpin orchards – satellite image analysis

To evaluate the extent, fire severity and recovery of bushland after the 2019-2020 bushfire, we used remotely sensed satellite images (Sentinel-2). Fire extent and severity mapping was undertaken for all five study orchards in Bilpin. The Sentinel-2images were used to characterize and quantify vegetation loss and recovery in bushland surrounding orchards in the Bilpin region after the fires. From the satellite images we were able develop a satellite-based greenness index to assess the vegetation condition at different time scales before and after the fire and thus monitor vegetation recovery following the fire event.

Floral resources around Bilpin orchards – ground surveys

To assess the diversity and abundance of co-flowering plants and their flower visitors within the orchard, we established nine 5×5 m quadrats in each of five orchards in Bilpin for PH15001. To complement this, nine 10×10 m quadrats were established and monitored in the surrounding bushland. During each survey, plants in flower were identified to species level and the percentage cover of flowering species within each quadrat estimated. Within each quadrat, surveys of insect visitation to all flowering plants were conducted in 5- minute observation periods, twice per sampling day, between 0800 and 1159 and again between 1200 and 1600. Surveys within each quadrat were conducted approximately every 6-8 weeks starting in September 2017 (PH15001) and continuing till 2023 under this project.

Crop pollinators and pollination services in Bilpin orchards – crop surveys

To assess the diversity and abundance of insects visiting the apple crop flowers, we conducted systematic surveys continuing the methodology of PH15001. We undertook 4 x 15 minutes observational surveys of insects visiting apple flowers on each survey day. These surveys focused on 15-trees per orchard row (x 2-rows: once in the morning, once in the afternoon) for Pink Lady apples on a single day. We aimed for four complete surveys at each of the five previously established apple orchards in Bilpin during spring bloom – i.e. two-surveys during king-bloom and two-surveys during full-bloom. In addition, on each day that an insect visitation survey was undertaken, we also did a crop phenology survey of 5-trees per row (the same 2-rows as for insect survey; 4-branches per tree). During each phenology survey the number of buds, open flowers and dehisced flowers were counted for the 4 study branches. These surveys provide a coarse metric of crop floral abundance and timing of the flowering season (king/peak bloom) during the insect survey.

Managed versus wild Honey bee abundance in orchards – marking experiment

To better understand pollination services by honeybees at the farm scale, we estimated the proportion of visits to crop flowers by honey bees from on-farm hives versus those from elsewhere (probably mostly wild bees). Marking blocks were fitted to the entrances of hives and filled with fluorescent paint powder following methods previously developed at WSU (Howpage et al. 1998). Foragers leaving the hive pass through the marking block and are dusted with paint that is identifiable by observers from metres away. This method allowed us to survey honeybees on the crop flowers and record each bee as either an on-farm hive bee (marked) or an off-farm, probably wild, bee (unmarked). There is a caveat that some unmarked bees may come from other managed hives on other properties, but the method still separates bees from on-farm hives from all others to all allow growers to see the contribution of managed bees from hives that they are renting.

Assessing the likely impacts of Varroa mite establishment on pollination

At the start of this project, Australia was the only major landmass with honey bees, but without their destructive enemy, the Varroa mite. However, by late 2023 it was accepted that Varroa was established in NSW and that eradication was no longer a realistic option. Varroa is particularly destructive to wild honey bee populations, which may decrease by >90%, reducing the "free" pollination services they provide to many horticultural industries in Australia (Cunningham et al. 2002). In addition, when Varroa mite reached New Zealand in 2000, the increase in hive mortality and in costs to manage the pest led to a rapid 50% decrease in the number of registered beekeepers (Iwasaki et al. 2015). The impact of Varroa mite establishment on Australian horticulture will depend on several factors, including:

a) What percentage of wild and managed honey bee hives are lost to Varroa mite

b) How large a role honey bees play in the pollination of a given crop

c) To what extent the loss of honey bees can be mitigated by actions of other pollinators

We can make informed guesses about a) based on the experience of other countries, but while the data are reasonable for managed hives the numbers are far less clear for wild colonies. Meanwhile, b) and c) are questions that we can already answer well for a few important cases, e.g. for almonds, honey bees are crucial and there is no viable alternative. However, for most crop x region combinations b) and c) are not well known (Rader et al. 2015). We had scope to make a case study of the likely impact of Varroa mite on apple pollination in Bilpin, using results from this project combined with our earlier results from PH15001.

Results and discussion

Vegetation around Bilpin orchards – satellite image analysis

Satellite images (Figure 1) show major changes to the vegetation in the Bilpin region before the fire (Figure 1 A) compared to one month after the fire event (Figure 1 B). Post-fire images show that there has been considerable vegetation recovery, but the effects of the fire on vegetation is still evident 2 years after the event (Figure 1 D).

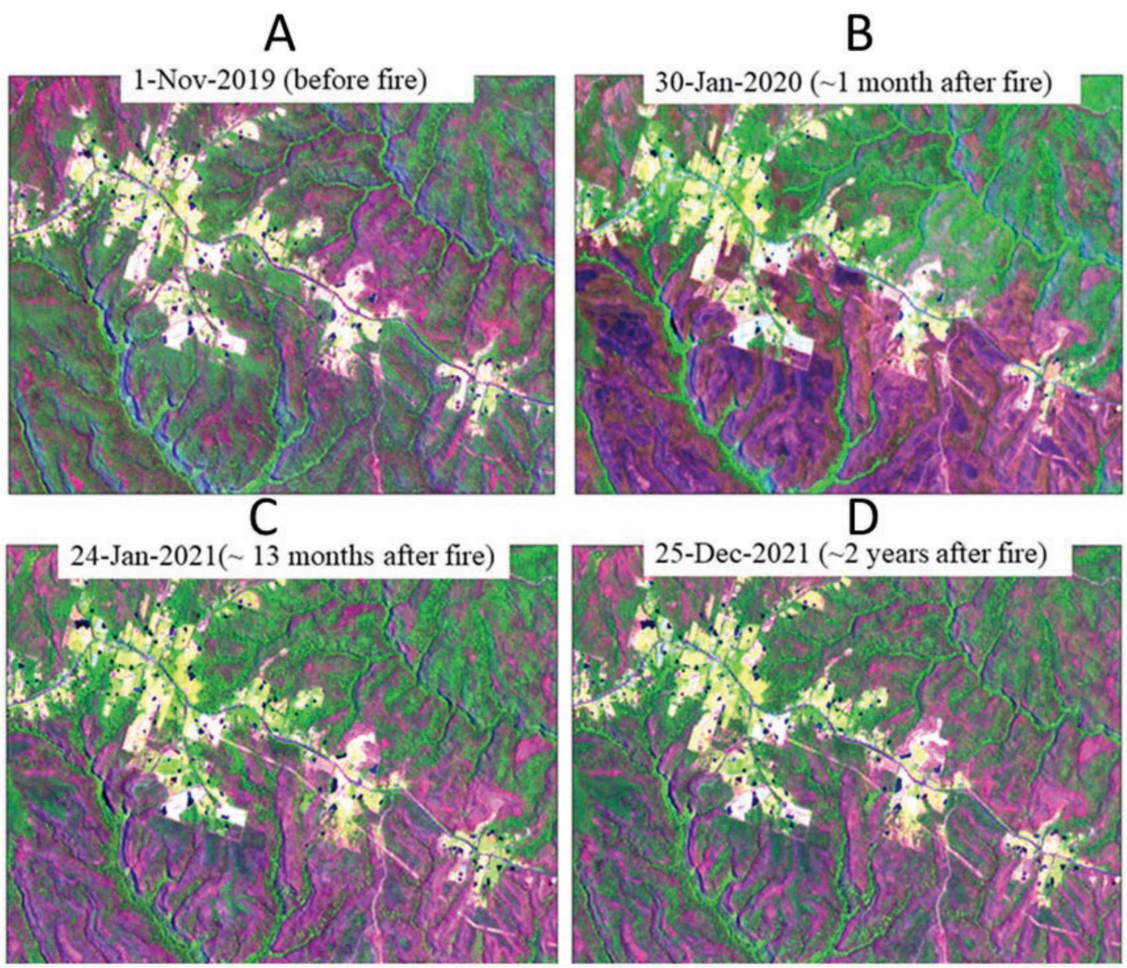

Figure 1. Time series of satellite images as a false colour composite showing vegetation condition before the fire event in November 2019 (A), one month after the fire event in January 2020 (B), 13 months after the fire event in January 2021 (C), and two years after the fire event in December 2021 (D). Green represents healthy vegetation and the purple represents fire damaged or less healthy\vegetated vegetation. The darker the purple the worse condition of the vegetation.

Further analysis of the time series of images (Appendix 1) showed that the vegetation surrounding the three orchards with lower severity fire damage recovered to approximately the pre-fire state about 9 months after the fire event. However, the vegetation around the two orchards with more severe fire damage was still below its pre-fire condition 9 months after the fire event. While the index (NDVI) calculated from these satellite images is a good indication of the greenness of vegetation and vegetation recovery, it does not necessarily indicate the ability of vegetation to flower and provide resources for pollinators, making the on-ground surveys a crucial component of assessing floral resource changes.

Floral resources and pollinators around Bilpin orchards – ground surveys

Following the fires, the return of flowering within plots in the fire-affected surrounding bushland started in July 2021 (7 months post fire) in 2 orchards and in August 2021 in the other three. This flowering was limited and consisted initially of only a few native species - *Caladenia picta* (orchid), *Drosera peltata* (shield sundew), *Lobelia dentata* and *Pimelea linearifolia* (slender rice flower). Apart from the orchid, these plants were visited by a range of different insects – *P. linearifolia* by honeybees, beetles, hoverflies and another fly, and *L. dentata* and *D. peltata* both by flies.

Overall, we observed 36 plants in flower in our bushland plots in the 3 years before the fire and 19 of these have not been recorded in flower since the fire. Since the fire, a considerably larger number (52 species), have been observed in flower and 35 of these had not been recorded in flower before the fire. Overall, 17 plant species were observed flowering both before and after the fire (Figure 3). These plant species attracted a wide range of flower visitors (Appendix 1) but the insect species observed differed considerably before and after the fires, and the difference was larger for the two farms surrounded by the most severely burnt bushland.

In the bushland plots, 14 flower-visiting insects were sufficiently common for numbers to be compared statistically before and after the fires. **Interestingly, both hoverflies (Syrphidae) and other flies increased in number following the fires**.

We also analyzed data on flower-visiting insects on non-crop plants (mostly weedy species) within the orchards. Here, the pre- v. post-fire differences were less marked and about 50% of flower visitor species were observed both before and after the fires. 15 insect taxa were observed in sufficient numbers for statistical comparison and **both honey bees and stingless bees (the two main visitors to apple flowers) decreased in numbers after the fire.**

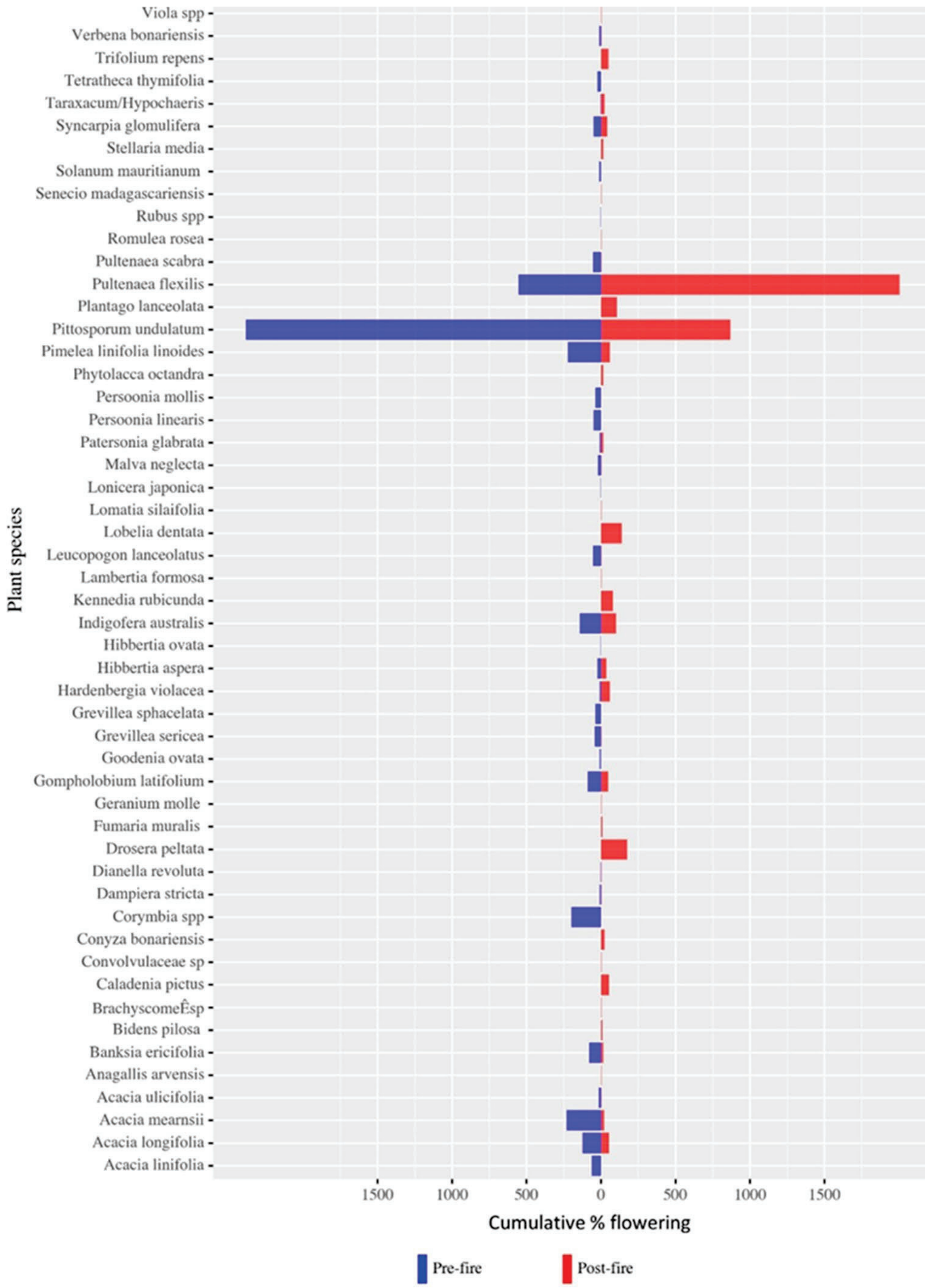

Figure 3. List of all plant species in flower and the percentage flowering observed within the surrounding vegetation matrix (all orchards combined) quadrats, before (blue; Sep 2017-Sep 2019) and after (red; Feb 2020- Dec 2021) fire. X-axis values show relative flowering abundance of each species calculated as the sum of % flowering values at quadrat level for each of the flowering species all orchards combined.

Crop pollinators and pollination services in Bilpin orchards – crop surveys

We undertook post-fire pollinator surveys in 2020 and 2022; but were precluded from doing so in 2021 by NSW Health COVID travel restrictions. We recorded over 21,000 insect visits to apple flowers in 2020 (n = 600 tree surveys) and 2022 (n = 520 tree surveys) respectively. As in pre-fire years, honeybees and stingless bees made up the large majority (typically around 90%) of apple flower visitors in the post-fire surveys (Figure 3). In the first post-fire flowering season (2020), honey bee and stingless bee numbers were within the range of visitation rates seen before the fires. However, in 2022, honeybee numbers were lower, and stingless bee numbers massively lower, than in all previous years (Figure 3).

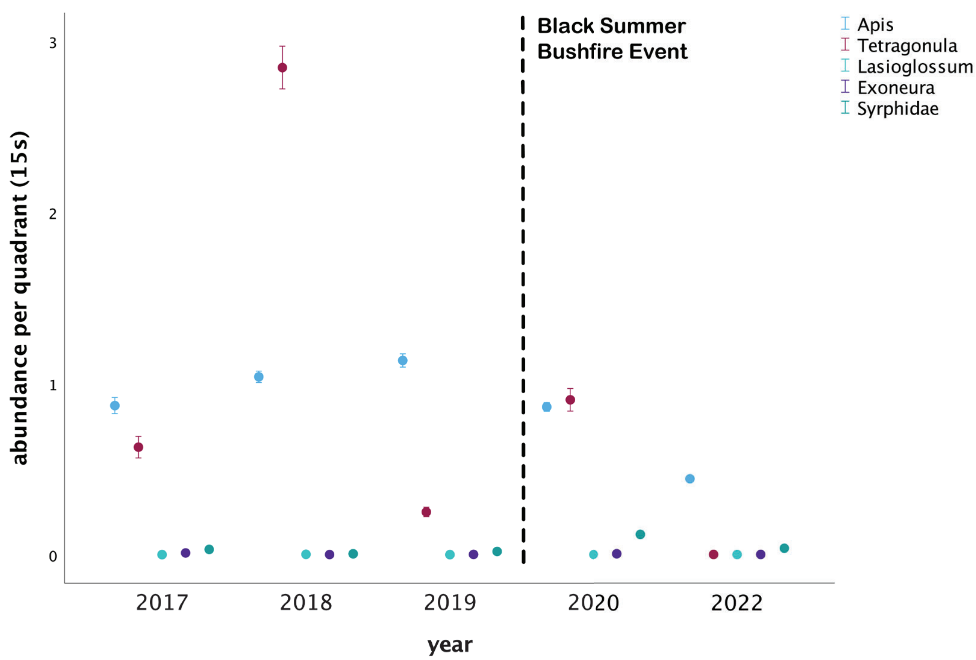

Figure 3. Abundance of the most common insect groups to visit apple flowers pre- and post-bushfire. Mean values with 95% confident intervals for honey bees (Apis), stingless bees (Tetragonula), allodapine bees (Exoneura) and hover flies (Syrphids).

Although tempting to attribute this decline to the influence of bushfires, it is almost certainly due to another extreme event – the weather (Figure 4). Spring 2022 marked the beginning of a third consecutive La Niña ENSO event for this region and temperatures during the 30-day Pink Lady *cv*. apple flowering period were unusually cool (only four days of above 20ºC). Our previous research for PH15001 shows that native bee visits to apple flowers in Bilpin are very limited below 22ºC, a temperature never exceeded during our 2022 surveys.

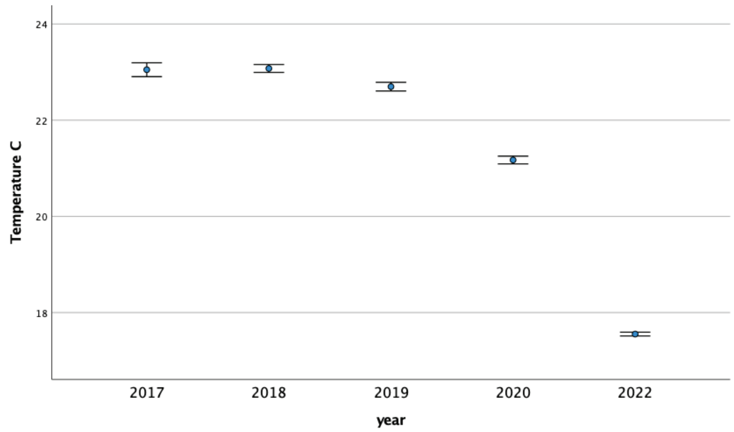

Figure 4. Mean ambient temperatures (℃ ±95% confidence intervals) recorded during apple bloom in Bilpin orchards 2017-22.

The unusually low temperatures during 2022 surveys (Figure 4) were likely the main cause of low visitation by all bees and especially stingless bees. This precludes firm conclusions about the recovery of native bee and wild honey bee populations post bushfire, but agrees with our previous findings that temperature is critical for native bee visitation to apple crops in NSW (Tierney et al. 2023).

Managed versus wild Honey bee abundance in orchards – marking experiment

Our mark-recapture experiment was successfully carried out in 2020 but was precluded by: (a) COVID travel restrictions in 2021; and (b) NSW DPI restrictions on honey bee hive movements in 2022 due to the Varroa mite incursion (Chapman et al. 2023). We undertook mark-recapture experiments across a time series (TS) of 10 days between mid-September and early October 2020, replicated in the morning and afternoon for a total of 20 surveys on an orchard that mainly produces apple, and to a lesser extent, pear and stone fruit.

Figure 5. Mark-Recapture experiment. Managed honey bees marked with red and green powdered-paint foraging on apple flowers at Shields Orchard, Bilpin NSW. Photo credit - James Cook.

The marking approach was a success (Figure 5) and, across the 20 surveys, we found very similar numbers of resident bees (WSU hives with marking blocks) and non-resident bees (feral colonies and/or unknown managed hives). Indeed, there were only two surveys (7 & 8) when these averages were significantly different, suggesting that approximately half of this orchard's honey bee pollination services were "free" ones coming from non-resident bees. We also know from chance observations that our WSU marked bees were foraging on other study orchards in

Bilpin, up to 2 km away, which is interesting both in terms of bee behaviour and the potential for cross-pollination between nearby orchards.

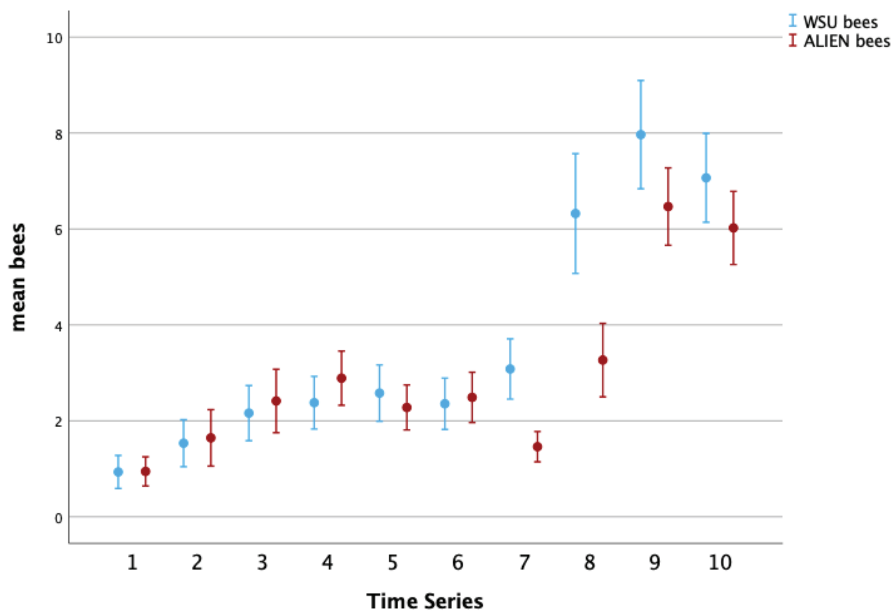

Figure 5. Crop flower visitation by resident honey bees from on-farm WSU hives (blue) versus non-resident honey bees (red)

Assessing the likely impacts of Varroa mite establishment on pollination

At the start of this project, Australia was the only major landmass with honey bees, but without their destructive enemy, the Varroa mite. However, by late 2023 it was accepted that Varroa was established in NSW and that eradication was no longer a realistic option. Our research for PH15001 established that, while some native solitary bees are excellent apple pollinators at an individual level (Bernauer et al. 2022, 2023), their generally low visitation rates to the crop mean that apple pollination in Australia is heavily reliant on honeybees (Tierney et al. 2023). In Bilpin, wild colonies of native stingless bees can also be important on days where temperatures exceed 22^{0}C, when they can outnumber honey bees. However, stingless bees do not occur in the other major apple regions of Australia, where the reliance on honey bees is even greater (Tierney et al. 2023, Brown et al. 2021).

Our marking experiment in Bilpin suggests that around 50% honey bee visits to apple flowers are from wild bees (or distant managed hives). If Varroa spreads to this region as now expected and decimates wild honey bee populations, at least in the short-term, then honey bee pollination services to apple could decrease to about half of the current level. There are some caveats to this estimate. First, it would be good to repeat the marking studies across more farms and seasons for a better estimate of the average contribution of non-resident honey bees. Second, it is difficult to know how quickly and how much Varroa will depress wild honeybee populations, although most experts believe that wild populations will be severely impacted based on what has happened in other countries (e.g. Iwasaki et al. 2015). Nevertheless, we appear to have evidence for a strong reliance on free apple pollination services from wild honey bees and therefore a high vulnerability to loss of pollination services as Varroa spreads. It is unfortunate that we were unable to replicate the experiment due to COVID and Varroa travel restrictions, but this research sets the foundation for a high impact scientific publication and provides valuable comparative data to our standard surveys of insect visitation, pre- and post-bushfire events. The outcomes should be of considerable interest to fruit growers and apiarists.

Outputs

Outputs are summarised below with reference to examples in the appendices.

Output	Description	Detail
Floral resource and pollinator survey results and recommendations	Results of year-round floral resource and pollinator surveys at 6-8 week intervals – info for growers and researchers	Results communicated in this milestone report and factsheets for growers (Appendix 4) Results to be communicated in a subsequent scientific journal article for researchers, currently detailed in Appendix 2
Results of satellite image analysis of vegetation changes	Results of collation and analysis of satellite images to monitor broader vegetation changes in cropping landscape intervals – info for growers and researchers	Results communicated in this milestone report and factsheets for growers (Appendix 4) Results to be communicated in a subsequent scientific journal article for researchers, currently detailed in Appendix 2
Results and recommendations of crop pollinator surveys	Detailed on crop pollinator surveys during crop flowering period – info for growers and researchers	Results communicated in this milestone report and factsheets for growers (Appendix 4) Results to be communicated in a subsequent scientific journal article for researchers, currently detailed in Appendix 1
Results and recommendations from honeybee marking experiments	Results and recommendations from on-crop honeybee marking experiments during the crop flowering season – info for growers and researchers	Results communicated in this milestone report and factsheets for growers (Appendix 4) Results to be communicated in a subsequent scientific journal article for researchers, currently detailed in Appendix 1
Evaluation of bushfire effects on pollination services	Evaluation of bushfire and Varroa threats for for growers	Evaluation communicated in this milestone report and factsheets for growers (Appendix 4)
Grower education and extension through on-going workshops, training, online information and publications	See detailed list of engagement / extension activities for stakeholders in Appendix 4	See detailed list of engagement / extension activities for stakeholders in Appendix 4
Final report to Hort Innovation	A final report to Hort Innovation detailing and discussing all findings and any recommendations forgrowers	This report

Outcomes

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
< List the outcome (e.g. knowledge, awareness, practice change, commercialisation, availability of new knowledge for next phase project) >	< Align to the relevant Fund outcome, strategy and KPI >	< Describe and define the outcome in terms of how it was realised by the target stakeholder group(s). Explain how the outcome is relevant at the Fund level >	< What forms of evidence were collected to identify and understand the outcome (e.g. survey, observation, feedback) >
Intermediate outcome: New knowledge on the impacts of bushfires on floral resources, wild pollinators, and pollination services to apples crops	2.2. Develop adaptive and tailored strategies to meet pollination requirements 2.4. Understand environmental and climatic barriers to effective pollination	Research carried out has shown how a major bushfire impacted floral resources, pollinator communities and crop pollination services	• Satellite images have been obtained and analysed (summary in milestone 103) • Floral resource surveys have been conducted 6-8 weekly • Pollinator crop visitation data collected in Y1 and Y3 post-fire. Y2 prevented by COVID restrictions
Intermediate outcome: Assessment of how extreme events may impact wild honeybee populations and the services they provide	1.1. Future-proof against endemic and exotic pests and diseases 2.1. Understand current and future pollination requirements	Research carried out has demonstrated major role for wild honeybees, which is now under threat from spread of Varroa	• Honeybee marking experiments carried out successfully in 2020, but not in 2021 (COVID lockdown) or 2022 (Varroa restrictions) • Honeybee abundance data were also obtained from the on-crop pollinator surveys in 2020 and 2022.
End-of-project outcomes: Has this research increased knowledge on how extreme events like bushfires affect crop pollination services?	1.1. Future-proof against endemic and exotic pests and diseases 2.1. Understand current and future pollination requirements 2.2. Develop adaptive and tailored strategies to meet pollination requirements 2.4. Understand environmental and climatic barriers to	Yes, as documented in this report and its appendices	• New knowledge documented in this report and Appendix 1 and 2

	effective pollination		
End-of-project outcomes: Translating research findings for Hort. growers through workshop / training and monitoring uptake of research / benefit	1.1. Future-proof against endemic and exotic pests and diseases 2.1. Understand current and future pollination requirements 2.2. Develop adaptive and tailored strategies to meet pollination requirements 2.4. Understand environmental and climatic barriers to effective pollination	Yes, as documented in the list of extension activities (Appendix 3) and illustrated in the compilation of extension materials (Appendix 4)	• List of extension activities (Appendix 3) • Compilation of extension materials (Appendix 4)

Monitoring and evaluation

Key Evaluation Question	**Project performance**	**Continuous improvement opportunities**
Has the project developed new knowledge that has been made available for industry uptake?	The research results reported in this report and in more detail in Appendix 1 and 2 describe valuable new knowledge. This is available via this report and extension and communication activities (Appendix 3).	Further studies in other cropping situations of the role of wild honeybees ahead of major spread of Varroa mite, followed by studies post-spread
Has the project generated information to guide the needs of horticultural growers? Have the implications for management practices been communicated to the relevant horticultural growers?	The recommendations listed in this report can guide needs of growers. They are communicated in this report and in fact sheets Appendix 4), as well as in grower articles, interviews, and other extension activities (Appendix 3).	Further communication of results of growers especially at grower events, including about the new threat to pollination services from Varroa
Have regular project updates been provided? How accessible were extension events to industry levy payers?	Regular project updates have been provided with the milestone reports throughout the project, and through extension activities (Appendix 3). Face to face extension events have focused mainly on APAL and DPI grower events, which are popular with growers.	Hort Innovation could run a podcast with a quarterly update on ongoing pollination projects
How has the project adapted to maximise research benefits?	The project faced significant challenges due to COVID and Varroa	

What influence is this research having on levy-payer productivity and profitability?	travel restrictions, but this has made our interpretation of results in the context of Varroa spread valuable. It is too early to say but good management of orchard floral resources and honeybees is now more important than at the start of the project due to the spread of Varroa.	

Recommendations

- **Practical application of the project findings**
    - Honeybees (managed and wild) are clearly the main pollinators of apples in most Australian apple growing regions, so activities to support their populations should benefit apple pollination services.
    - The spread of Varroa is likely to dramatically decrease wild population of honeybees in the next few years, so where wild honeybees make an important contribution to crop pollination, there may be more need for managed hives.
    - Patterns of pollinator activity are highly dependent on weather and especially temperature. In particular, while native bees can be quite numerous at higher temperatures, below about 20C honeybees are the only numerous apple flower visitors.
    - Several native bees are good apple pollinators but they are rarely sufficiently numerous to offer an alternative to honeybees. Stingless bees In the Bilpin region and reed bees (*Exoneura*) in the Yarra Valley are exceptions and activities (floral plantings for both, nests sites for reed bees) to support these may benefit pollination of apple (and e.g. cherry) crops.
    - Following a major bushfire close to orchards, there was no flowering within plots in the fire-affected bushland areas until at least seven months after the fire and, even then, there were few species in flower. Therefore, it may be important to boost no-crop floral resources on farms following bushfire events to attract and support both wild pollinators and managed hives.
- **Possibilities of future RD&E that directly flow from the work undertaken and its results**
    - Our approach to estimating the relative contributions to crop pollination of honeybees from on-farm hives and those from elsewhere (wild bees or distant managed hives) was successful and showed that about 50% bees on the crop were from elsewhere (probably mostly wild). This approach could be widely applicable for researchers wanting a better understanding of the role of wild honeybees in pollinating the crop in a given situation.
    - If implemented soon to get baseline data, this approach may also allow estimation of the loss of pollination services caused by the spread of varroa over the next few years
- **Development and adoption activities that would ensure full value from the project's findings for industry**
    - Our approach to estimating the relative contributions to crop pollination of honeybees from on-farm hives and those from elsewhere could be widely applicable for growers wanting a better understanding of who is pollinating their crop and the value of rented hives in terms of pollination contribution.

Refereed scientific publications

This project PH20002 continues a line of work from the previous project PH15001, using the same methods, following an extreme bushfire event. Due to the lengthy process of publishing in scientific journals, some key papers from PH20002 have been published during the timeline of PH20002 and are listed below. These are highly relevant to PH20002 since they describe the situation at the study orchards for three years before the fire event. Subsequent "post-fire" publications are in preparation but not yet published, while Chapman et al. (2023) is a mini-review of the threats and opportunities posed by the 2023 Varroa invasion in Australia.

Journal articles

Chapman, N. C., Colin, T., Cook, J., da Silva, C. R. B., Gloag, R., Hogendoorn, K., Howard, S. R., Remnant, E. J., Roberts, J. M. K., Tierney, S. M., Wilson, R. S., & Mikheyev, A. S. (2023). The final frontier: ecological and evolutionary dynamics of a global parasite invasion. *Biology Letters*, *19*(5), 20220589. https://doi.org/10.1098/rsbl.2022.0589

Bernauer, O. M., Cook, J. M., & Tierney, S. M. (2022). Division of foraging behaviour: Assessments of pollinator traits when visiting a model plant species. *Animal Behaviour*. https://www.sciencedirect.com/science/article/pii/S0003347222000896

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Gilpin, A.-M., Kobel, C., Brettell, L. E., O'Brien, C., Cook, J. M., & Power, S. A. (2022). Co-flowering species richness increases pollinator visitation to apple flowers. *Collection FAO: Agriculture*, *12*(8), 1246. https://doi.org/10.3390/agriculture12081246

Tierney, S. M., Bernauer, O. M., King, L., Spooner-Hart, R., & Cook, J. M. (2023). Bee pollination services and the burden of biogeography. *Proceedings. Biological Sciences / The Royal Society*, *290*(2000), 20230747. https://doi.org/10.1098/rspb.2023.0747

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Intellectual property

'No project IP or commercialisation to report'

Acknowledgements

We thank the growers who have supported and hosted our research in Bilpin for the duration of this project (as well as the previous project PH15001) and the members of the Project Reference Group for their interest and feedback on results and plans.

Appendices

Appendix 1. Technical report on crop pollinator surveys

Appendix 2. Technical report on landscape and flora surveys

Appendix 3. List of translation and extension activities

Appendix 4. Compilation of grower-focused outputs

Appendix 3. List of translation and extension activities

February 2024

- Dr Simon Tierney – Apple and Pear Australia Limited (APAL) Future Orchards Harvest Events in Orange and Batlow (5-8 February 2024) to networking and communicate results with major industry partner, fruit growers and state government (NSW DPI) representatives.

November 2023

- Dr Amy Marie Gilpin, HIE, presented at the Australian Entomological Society Conference in Albany WA, 14 November, **'How are flowering plants and pollinators affected by fire and the indirect consequences for pollination services within orchards'**. Amy-Marie Gilpin, Rakhesh, Devadas, Andrew A Williamson, Sally A. Power, and James M. Cook

October 2023

- Australian Fruit Grower Magazine Articles, State Roundup NSW **'Apple Pollinator Study Published'**, p19 & **'Valuable insights shared at APAL Technical Symposium 'A Native Pollinator Alternative'**, p34 –36.

- Sydney Basin Fruit Growers Meeting, Growers, NSW DPI Batlow, Orange, Agricultural Department & Digital Communications. Shields Orchard, Bells Line of Road, Bilpin NSW, 18 October 2023

September 2023

- Dr Amy Marie Gilpin, HIE, was quoted on Channel 9 News about the varroa mite eradication program. "After 15 months and more than 14,000 destroyed beehives, Australia has abandoned its efforts to eradicate the varroa mite and will instead transition towards managing the deadly parasite" September 20, ***Syndicated by Bnn.network**, Agriculture online.*

- Talk - '***The importance of biological history for pollinator dependent crop',*** Hawkesbury Beekeepers Club (branch of Australian Amateur Beekeepers), Friday 1st September 2023 at the Hawkesbury Leisure and Learning Centre, Richmond NSW, Dr Simon Tierney, WSU - https://www.beekeepers.asn.au/hawkesbury

August 2023

- Talk - '***Pollinator-dependent food crops: the effects of biological history on modern production - A native pollinator alternative'?*** at eh APAL Technical Symposium, August 9, 2023, Shepperton Victoria, Dr Simon Tierney, WSU - https://apal.org.au/valuable-insights-shared-at-apal-technical-symposium/

- Article - ***'Australian study assesses Stingless Bees as Horticulture Pollinators'*** - Farmers Weekly, "new research led by WSU & HIA has delivered the most comprehensive assessment of pollination in apple crops in Australia by exploring pollination services provided by native and non-native bees for apple cultivation in Australia", August 14. Professor Cook was also interviewed on ABC Mildura regarding this, *covered also by Gold Central Victoria and Magic 89.9,* - Aus study assesses stingless bees as hort pollinators (farmersweekly.co.nz)

July 2023

- Article - ***'Why introduced insects are essential for pollinating apples***' *'Good Fruit & Vegetables* published on-line on Saturday 29 July 2023, Dr Simon Tierney, WSU and HIA - https://www.goodfruitandvegetables.com.au/story/8268512/why-introduced-insects-are essential-for-pollination/?cs=28086.

- Article -*Australian Associated Press*, '***Apples, bees, mites and the pollination gauntlet',*** syndicated by 111 other news outlets, 8 July 2023, Dr Simon Tierney, https://www.aap.com.au/news/apples-bees-mites-and-the-pollination-gauntlet/

- Interview - ***'Why introduced insects are essential for pollinating apples'***, ABC Radio's Rural Report, syndicated across 9 ABC Rural stations in NSW and Victoria. Covered also by River 1467, 2WEB Outback Radio, 5RM Radio, and Gold Central Victoria, ABC Country Hour and syndicated across the ABC Radio regional network (July 5th), and 891 ABC Adelaide interview, syndicated by regional South Australia and Broken Hill ABC Radio, Nepean News (July 7th) and The West Australian, Syndicated by Daily Mail and 110 others. Also covered by The Land (10th July), Dr Simon Tierney, WSU.

June 2023

- Interview- ***'Study finds apple pollination in Australia reliant on introduced species'***, Swan Hill News June 16th, leading story on Libby Price's *Country Today* radio show airs throughout all of rural VIC and a large portion of NSW, Dr Simon Tierney, WSU -https://www.westernsydney.edu.au/newscentre/news_centre/more_news_stories/study_finds_apple_pollination_in_australia_reliant_on_introduced_species

May 2023

- Publication - Tierney SM, Bernauer OM, King L, Spooner-Hart R, Cook JM (2023). ***Bee pollination services and the burden of biogeography***. Proceedings of the Royal Society Of London B 290: 20230747 https://royalsocietypublishing.org/doi/10.1098/rspb.2023.0747

- Publication - Chapman NC, Colin T, Cook JM, da Silva CRB, Gloag R, Hogendoorn K, Howard SR, Remnant EJ, Roberts JMK, Tierney SM, Wilson RS, Mikeyev AS (2023). ***The final frontier: ecological and evolutionary dynamics of a global parasite invasion****. Royal Society Publishing, Biology Letters* 19: 20220589.
DOI: https://doi.org/10.1098/rsbl.2022.0589

- Article – ***'Australia is in a unique position to eliminate the bee-killing Varroa mite. Here's what happens if we don't'.*** *The Conversation*, Science + Tech, 24 May 2023, Dr Simon Tierney, WSU, Scarlett Howard, Monash, Alexander Mikheyev, ANU, Emily Remnant, Uni of Sydney, Theotime Colin, MQ.
https://theconversation.com/australia-is-in-a-unique-position-to-eliminate-the-bee-killing-varroa-mite-heres-what-happens-if-we-dont-205926

- Interview - ***'Honeybees in native environments',*** ABC radio interview, part of the Painted River Project at The Gully in Katoomba (11.30am mark on recording). Amy also had pamphlets on show and spoke to the public about pollinators in the swamp. There were in excess of 200 people in attendance. The public were also invited to undertake their own pollinator research and were shown how to use sweep nets and identify insects, May 28, Amy-Marie Gilpin, WSU - https://www.abc.net.au/sydney/programs/weekendmornings/weekend-mornings/102375162

- Talk - ***'From precipitation to pollination: water a key ingredient for dynamic ecosystem services',*** part of the Water Sensitive Urban Design symposium for the Painted River Project and Western Creative's Upland Swamp exhibition, 9th May, Amy-Marie Gilpin WSU.

- Talk with Q&A session - James Cook presented an evening webinar and discussion (https://fb.me/e/4bTEzxm2l) for the Permaculture Society on the impact of Varroa and alternatives to honeybees for fruit and vegetable pollination. 11th May

April 2023

- Grower Field Day, - Amy Gilpin attended the DPI PIPS 3, field day at Orange (26/4/23), showcasing current research by DPI, Tasmanian Institute of Agriculture and Agriculture Victoria on integrated pest and disease management, soil health and climate challenges. The field day brought together researchers and local growers from across NSW and provided opportunity to discuss our work with growers and DPI colleagues.

March 2023

- Interview - ***'The Birds and bees, career advice with pollination ecologist Dr Amy Marie Gilpin'***, March 9 - https://www.conservation-careers.com/conservation-jobs-careers-advice/interivews/the-birds-and-the-bees-career-advice-with-pollination-ecologist-dr-amy-marie-gilpin/

February 2023

- Presentation – ***'Researching Plant-Pollinator Interactions and fire'***, Kurrajong North Rotary Club, Amy-Marie Gilpin, 28th Feb.

- Presentation - ***'How to identify and encourage pollinators in your garden'?*** Uniting Hawkesbury (Richmond) Residential Aged Care, Amy-Marie Gilpin, WSU

- ***Pollinator guides***, Wheen Bee Foundation – Southern Eastern highlands, SE NSW Coast & Sydney Basin Coast Brochures (Blue Mountains released previously) -Amy Marie Gilpin & Team - https://www.wheenbeefoundation.org.au/our-work/projects/powerful-pollinators/

December 2022

- Poster presentation ***"How are flowering plants and pollinators affected by fire and the indirect consequences for pollination services within orchards"***, at the Ecological Society of Australia Conference Dec, 2022. James Cook, Andrew Williamson, Rakhesh Devdas and Sally Power, WSU.

November 2022

- Talk -Pollinator Week, Hawkesbury Library - ***'Understanding plant-pollinator interactions in Australian ecosystems and how to support them'*** - Part of Bushfire - Plant-pollinator interactions under a changing environment, Amy-Marie Gilpin & HIE Students Matthew Cunningham & Sindhu Sheoran, 14th November, 2022.

- Pollinator Week - ***Understanding the impact of climate change on Australian pollinators and systems***, Hawkesbury Library as part of 14 November, 2022.

August 2022

- Publication - Gilpin, A.M., Kobel, C., Brettell, L.E., O'Brien, C., Cook, J.M. and Power, S.A., 2022.' **Co-Flowering Species Richness Increases Pollinator Visitation to Apple Flowers**. *Agriculture*, *12*(8), p.1246.

June 2021

- Orchard Bushfire Recovery Industry Meeting, Online Webinar, HIA/DPI NSW project meeting for seasonal activity led by Bruno Holzapfel and Kevin Dodds; including Jessica Fearnley, John Golding, Michael Idowu and from PIRSA-SARDI Tim Pitt and Paul Petrie; WSU representative Dr Simon Tierney.

December 2021

- Poster - "Understanding the impact of bushfire on plant- pollinator interactions at the interface between agricultural and native landscapes", Ecological Society Conference 2021, Andrew Williamson, James Cook, Sally Power. Amy-Marie Gilpin.

June 2020

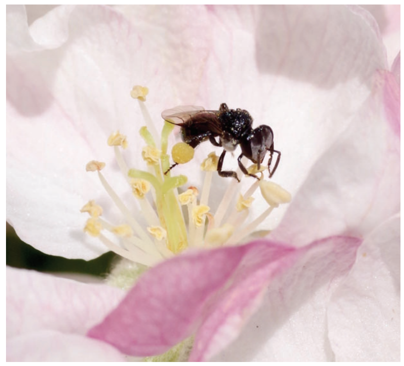
- Talk – ***'Key issues, problems, capacity and significance of bushfire on bee pollination and ecosystem services'***, Bushfire Research Theme Storm WSU University wide Research Event, online Webinar, 1 June 2020, Dr Simon Tierney and Dr Amy-Marie Gilpin.

Apple Pollinators in New South Wales and the Varroa Mite Threat

WESTERN SYDNEY UNIVERSITY
Hawkesbury Institute for the Environment

Apple is a major crop in Australia and NSW accounts for about 10% of national production in regions such as Batlow, Orange and Bilpin. Most cultivars require or benefit from cross-pollination by other apple varieties and insects are the main vectors of pollen between flowers on different trees. High quality fruits require adequate pollination of at least 6-7 seeds (of 10) in an apple flower and we found evidence for pollen limitation in Bilpin and Orange.

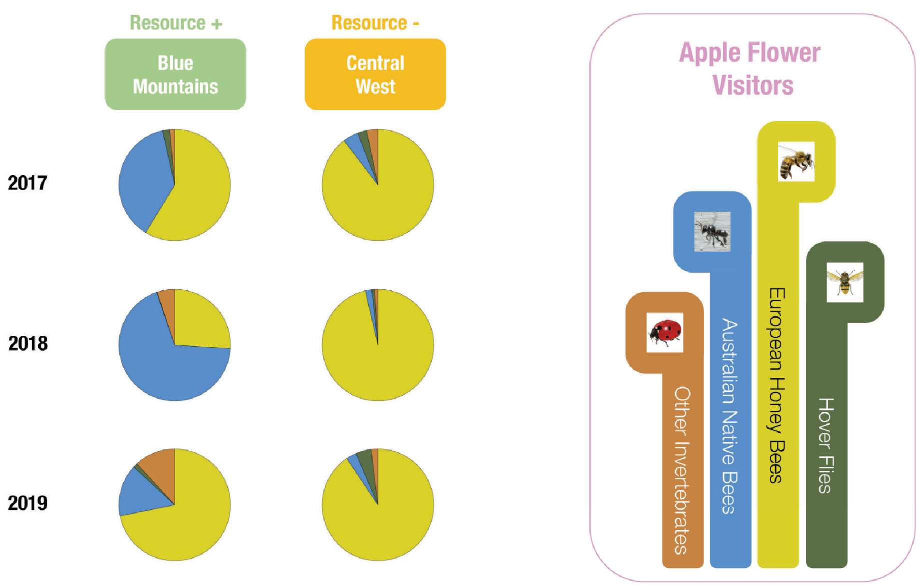
Honeybee (*Apis mellifera*) – marked with red dye for an experiment



Stingless bee (*Tetragonula*)

Reed bee (*Exoneura*)

APPLE POLLINATORS Our extensive surveys of apple flower visitors on several farms in the Bilpin and Orange growing regions, over three flowering seasons, show that honey bees and native bees are by far the main insects involved, with a smaller contribution from other insects, such as hoverflies.

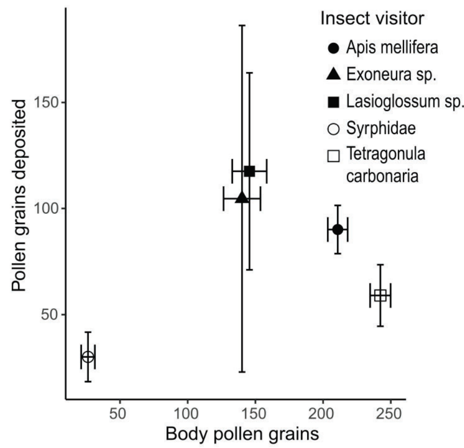


Pie charts show variable composition of apple flower visitor assemblages across years and two regions. However, honeybees followed by native bees clearly dominate the numbers

Overall, honeybees and native bees account for almost 90% of apple flower visits, but while honeybees are dominant in both regions, there is also a large contribution by native stingless bees (*Tetragonula carbonaria*) in Bilpin (see figure above)

POLLEN DEPOSITION

Our experiments show that stingless bees and some other native bees both carry and deposit more pollen per visit on apple stigmas than do honeybees. However, the much greater numbers of honey bees make them the main pollinators of the crop overall.

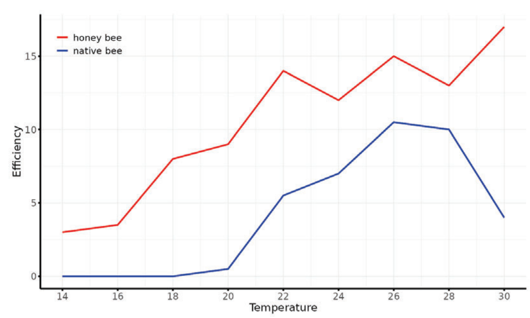


THE VARROA THREAT

The Varroa mite was detected in NSW in mid-2023 and is now considered established beyond possibility of eradication (link). It is a parasite specific to honey bees and does not attack other bees or other insects. While control measures remain important, spread is inevitable and feral honey bee hives are expected to decline greatly in regions affected. Since apple pollination relies heavily on honeybees, some regions may face a considerable loss of current "free" pollination services from feral honey bees and become more reliant on managed hives and on native wild pollinators.

WEATHER AND CLIMATE

Weather influences pollinator efficiency greatly and activity is lower on overcast or rainy days. However, species respond differently to temperature. In particular, we found that apple flower visitation by native bees in general was limited by low temperatures, when honeybees (and smaller numbers of flies) dominated. In particular, native stingless bee numbers are negligible until the temperature is >20C, but can be very numerous at higher temperatures.



REGIONAL VARIATION

Overall, apple pollination in Australian growing regions depends heavily on honey bees, which often make up about 90% of flower visits. However, some native bees can be locally significant too. In particular, stingless bees can outnumber honey bees on warm days in Bilpin but are, unfortunately, not found in other apple regions. Meanwhile, we found that solitary halictid bees were sometimes numerous (again on warmer days) in Orange, and other work has shown that reed bees (*Exoneura*) can be locally common apple visitors in Victoria's Yarra Valley.

FIND OUT MORE

NSW apple pollinators:
http://doi.org/10.1098/rspb.2023.0747
Pollination efficiency and outcomes:
https://doi.org/10.1016/j.agee.2022.108063
Varroa Situation:
https://www.dpi.nsw.gov.au/emergencies/biosecurity/current-situation/varroa-mite-emergency-response

FUNDING STATEMENT

This research was funded by the Hort Frontiers Pollination Fund, part of the Hort Frontiers strategic partnership initiative developed by Hort Innovation under Projects PH15001 and PH20002 with co-investment from Western Sydney University, Syngenta, Bayer, Greening Australia and OLAM.

Powerful pollinators

Encouraging insect pollinators in farm landscapes

Pollinators are an essential component of agricultural production and of healthy, biodiverse landscapes. Protecting and enhancing pollinator resources on farms will help support a diverse range of pollinators. This brochure provides an introduction to encouraging insect pollinators on farms, including a guide to choosing plants that will support diverse pollinators throughout the year.

WHEEN BEE FOUNDATION

The power of pollinators

Pollinators – mostly insects, but also birds and mammals – assist the formation of seeds and fruit in many plant species by visiting flowers in search of food (nectar and/or pollen). Whilst foraging they transfer pollen from one flower to another, facilitating fertilization, which results in fruits and seeds.

Honey bees, native bees and other native insects like hoverflies, wasps and butterflies provide essential pollination services for native plants, garden flowers, fruits and vegetables.

Native vegetation supports pollinators by providing food and nesting sites. Nearby crops and pastures will benefit from the increased abundance and diversity of pollinators in the landscape.

Pollinators and food security

Without insect pollinators, the quantity and diversity of food and flowers grown in backyard gardens would be severely restricted. Many of the foods we eat, from gardens and farms, benefit from pollination.

Pollinator-dependent foods include citrus, apples, stone-fruits, zucchini, pumpkins, strawberries and tomatoes, as well as plants grown for seed such as sunflowers, coriander and parsley.

The quantity and diversity of insect pollinators are key drivers of production as they influence both food yields and quality. Under-pollination results in smaller and misshapen fruit or seed that isn't viable to grow.

A diverse and healthy community of pollinators generally provides more effective and consistent pollination than relying on any single species.

Pollinators are essential to, and dependent upon, healthy ecosystems. A growing human population and increasing demand for food puts pressure on ecosystems, with potential negative impacts on biodiversity, the environment and food production.

Insect populations are in decline worldwide due to land clearing, intensive or monocultural agriculture, pesticide use, pollution, colony disease, increased urbanisation and climate change. Low pollinator numbers mean not all flowers are pollinated, leading to low fruit or seed set. This in turn reduces fruit and vegetable harvest yields, and decreases food supply.

Under-pollination results in smaller, misshapen fruit such as this strawberry.

Backyard biodiversity

Insect pollinators are a prime example of the importance of healthy ecosystems in urban gardens, parks and reserves. Insects are the 'canaries in the coal mine' of our urban and rural environments. Without our 'littlest creatures', we lack pollinators, natural beneficial pest control services, and critical food source for other insects, birds, amphibians, reptiles and mammals.

The presence of connected and widespread pollinator habitat is critical to support insect populations if we are to maintain sustainable cities and productive, healthy gardens and urban farms for food security and biodiversity.

Pollinators require habitat that contains year-round food sources, breeding resources and nesting sites. The presence of pollinator habitat adjacent to food crops has been shown to improve food production by enabling a greater variety and number of pollinators to persist year-round, providing pollination services when required.

Turn to the centre of this brochure for a guide to planting for pollinators.

Diapause or diet? Where are the insects?

Many insect pollinators undergo a diapause during colder winter months. Diapause is a period of suspended development during unfavourable environmental conditions, and during this period insect pollinators do not need flowers. Birds and other small mammals will continue to benefit from available pollen and nectar during this time.

If there are low numbers of insect pollinators in your local area, it is important to determine whether this is because of diapause, or because of an inadequate availability of nectar and pollen creating a 'food desert' where insect pollinators cannot survive.

There are still many unknowns about insect pollinators in Australia. Take part in Australian Pollinator Week or in the bi-annual Wild Pollinator Count to learn more about pollinators in your area — visit **AustralianPollinatorWeek.org.au** and **WildPollinatorCount.com**

Encouraging pollinators in your garden

Create pollination reservoirs

Pollination reservoirs are areas that provide floral resources for pollinators. They can be gardens, new planting or existing habitat such as established trees, or even local bushland, parks or reserves. A high diversity of plant species is essential to provide nectar, pollen and nesting sites throughout the year. Pollination reservoirs need to be close enough to where pollinators live to ensure that they can fly easily to them.

Improve on what you have

Enhance and improve your existing pollinator habitat where possible. Gardens that already contain established trees, rockeries, ponds, bare soil and organic matter, and a variety of flowering plants, are a valuable resource for beneficial insects and pollinators.

Nature-strips, verges, laneways, vegetable gardens, orchards, nature reserves, and riverbanks and creeks can all be important pollinator-attracting areas. Protect and enhance native pollinator plants in your garden and surrounds for the future.

Plant trees, shrubs and groundcovers

Planting a variety of species of groundcovers, shrubs and trees to in your garden will further attract pollinators to your patch. Initial watering and protection will improve the success rate of young plants. Some species such as wildflowers or native pea species are excellent pollinator attractors and reward careful attention by keen gardeners.

Be a citizen scientist and do some detective work to discover local pollinators in your patch. Visit **inaturalist.ala.org.au** to be involved.

Construct insect real estate

Insect hotels, which are both functional and attractive, are a great way to add to habitat and nesting places for pollinators and insects in your backyard or garden. The hotels are easily moved to be close to flowering plants and those needing pollination, especially if you have a new garden that is still growing. Include lots of different sized holes, cracks and crevices to provide homes for various solitary insect pollinators.

Plant for the future

When establishing pollinator habitat, consider including species that are indigenous to your area but can tolerate increasingly drier and warmer conditions, to create resilient habitat for climate change. Rehabilitate weedy areas into managed pollination reservoirs by introducing lots of flowering plant diversity. Be careful not to plant invasive or listed weeds, and look for suitable replacements.

Amplify the flower signal

Plants have evolved large flowers or clusters of smaller flowers because they attract more pollinator visits. Large, colourful and diverse plantings attract more pollinators. Ideally, plant in groups that contain different vegetation layers — combine a species-rich mixture of wildflowers, ground-covers, herbs, lilies, rushes, climbers, shrubs and trees.

Connectivity counts

Insect pollinators benefit from greater connectivity of habitat in a landscape, which allows them to forage over a wider radius and increase in numbers in a local area. Encourage friends and neighbours to plant for pollinators and create connections in your community.

Get to know your local flora

Your local government area has distinct populations of insects, depending on the local flora and environment. Knowing your local insect species will help you develop better plantings.

The plants growing in nearby nature reserves or bushland will be suited to your climate and soils. Local environment groups and specialist native nurseries can provide information about local plants.

Grow a bumper crop

Pollinator-attracting plants include many fruits and vegetables grown in backyards, community and market gardens, and orchards. Pollinators ensure good yields of crops such as apples, beans, avocado, and almonds, and bush foods such as lilly-pilly and yam daisy.

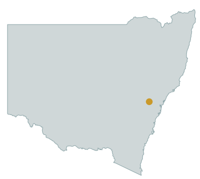
Reduce chemical use

Insecticides, fungicides and herbicides all affect bee, colony and wild pollinator health. Herbicides can impact pollinators by reducing the availability and diversity of flora and removing vegetation that helps support insect life. Some herbicides can also harm the beneficial bacteria in the insect gut. Insecticides are an obvious threat to pollinators, yet many pollinators will, in healthy numbers, help control pest insects, ultimately reducing the need for insecticide use.

Many crops are dependent on pollination by bees. When chemical pest control is unavoidable, select products that are least harmful for pollinators and apply insecticides in the evening or at night when pollinators are not active. Always use according to directions, especially for withholding periods, and notify beekeepers a few days before spraying chemicals so beehives can be safely relocated away from harm.

Safeguard the bees? The best way to 'save the bees' and protect our pollinators is to create an abundance of diverse habitat — from the ground up! There is much interest in keeping a bee hive to promote pollinators, but there are serious legal and biosecurity responsibilities that must be considered, and that the introduction of a bee hive does not displace existing native pollinators and insects. Be a friend of pollinators and say it with flowers!

A guide to planting for pollinators for Bilpin, Blue Mountains



Healthy populations of insect pollinators are important for sustainable and resilient farms, orchards, gardens, and native flora.

This Guide will help you select plant species to attract and sustain pollinators in agricultural areas and gardens throughout the year.

The Bilpin region, in the Blue Mountains bioregion of New South Wales, is defined by sedimentary soils and sandstone plateaux, and undulating topography, punctuated by rocky gorges and outcrops. Climate is cool to cold (occasional frosts and snowfall at altitude) in winter, with mild to warm summers. Vegetation communities include open woodlands and heathland, as well as escarpment and riparian (streamside) communities, open forest and rainforest.

The plants listed in this Guide will help supply rewards to pollinators, with an emphasis on species that are indigenous and suited to local climates.

Garden centres sell many common pollinator-attracting ornamental flowers and herbs labelled as 'bee-friendly'.

The eucalypt species in this Guide are mostly large trees, and not suitable for all gardens, but have been included for their value as good nectar producing species. Most eucalypts do not flower every year, so choosing diverse species will help create continuously flowering habitat.

The pollinator plant list

To create pollinator-attracting plantings, use the Guide to choose a selection of plants with a variety of flower colours, different growth habits and a range of flowering seasons.

For each species, the planting Guide lists:

- life-form/'habit' (climber, herb, shrub or tree) and height (m).
- the vegetation type in which they naturally occur
- flower colour and flowering season
- growth requirements (sun/shade, moist/dry)
- insect groups that may visit each plant and the floral reward (pollen and/or nectar).

The coloured bars indicate the flowering months for each species. Darker shading denotes the peak flowering period, with a lighter shading for non-peak flowering months. Flowering dates may differ between regions and seasons, particularly for non-peak times, if your local climate is consistently warmer or cooler than average, with earlier or later flowering.

Sourcing plants

Most of the plant species listed are available from retail or wholesale nurseries or native plant growers, and local environment groups. If you can't source these plants at your local garden centre, or indigenous nursery, ask them to contact the local wholesale nursery suppliers and plant growers listed online. See the reverse of the Guide for details.

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Lifeform	Common name	Scientific name	Family	Vegetation type	Height	Flower colour	Flowering												Aspect	Soil moisture	Pollinator reward		Visitation by pollinator							
							Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			Pollen	Nectar	Native bees	Honey bees	Hoverflies	Wasps	Butterflies	Moths	Beetles	Flies
Bilpin																														
Climber	Purple Twining Pea	*Hardenbergia violacea*	Fabaceae	Woodland, Forest	> 3 m	Mauve							■	■	■	■			Sun	Well drained	●	●	●	●						
Climber	Dusky Coral Pea	*Kennedia rubicunda*	Fabaceae	Woodland, Forest	> 3 m	Red							■	■	■	■	■	■	Part sun	Well drained	●	●	●							
Forb	Toothed Lobelia	*Lobelia dentata*	Lobeliaceae	Woodland, Forest	0.4 m	Blue Purple	■	■					■	■	■	■	■	■	Semi-shade	Well drained	●	●			●					
Forb	Leafy Purple Flag	*Patersonia glabrata*	Iridaceae	Heath, Woodland	0.5 m	Pale Violet									■	■	■		Sun to semi-shade	Well drained to moist	●	●			●				●	
Forb	Yellow Paper Daisy / Golden Everlasting	*Xerochrysum bracteatum*	Asteraceae	Forests	0.2–0.7 m	Yellow	■	■	░	░	░	░	░	░	░	░	░	■	Sun	Well drained	●	●			●	●	●	●	●	●
Herb	Blueberry Lily / Blue Flax Lily	*Dianella revoluta var. revoluta*	Liliaceae	Forest, Woodland	0.7 m	Blue-violet, Stamens Yellow													Semi-shade	Moist well drained	●	●	●							
Herb	Vanilla Plant / Rush Lily	*Sowerbaea juncea*	Asparagaceae	Heath	0.45 m	Purple, Yellow										■	■	■	Sun to semi-shade	Wet, intermittently waterlogged	●	●	●				●	●	●	
Shrub / Small	Blue Dampiera	*Dampiera stricta*	Goodeniaceae	Open forest, Heath	0.5 m	Blue, Purple							■	■	■	■	■	■	Sun to semi-shade	Well drained	●	●	●		●				●	●
Shrub / Small	Rough Guinea Flower	*Hibbertia aspera*	Dilleniaceae	Forest, Woodland, Heath	0.6 m	Yellow								■	■	■	■	■	Sun to semi-shade	Well drained to moist	●	●			●				●	●
Shrub / Small	Trailing Guinea Glower	*Hibbertia empetrifolia*	Dilleniaceae	Open forest, Heath	0.4 m	Yellow	■	■	■						■	■	■	■	Sun	Well drained	●	●			●				●	●
Shrub / Medium	Prickly Moses	*Acacia ulicifolia*	Fabaceae	Open forest, Woodland	2 m	Yellow					■	■	■	■	■	■			Sun	Well drained	●		●	●	●	●	●	●	●	●
Shrub / Medium	Hairpin Banksia	*Banksia spinulosa*	Proteaceae	Woodland	2 m	Yellow, Hooks Dark Red/black				■	■	■	■	■					Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Dogwood / Dollybush	*Cassinia aculeata*	Asteraceae	Forest, Woodland, Heath	2 m	White	■	■	■								■	■	Sun to semi-shade	Moist well drained	●	●			●		●	●	●	●
Shrub / Medium	Parrot Pea (eggs & bacon)	*Dillwynia elegans*	Fabaceae	Woodland, Dry heath	1.5 m	Yellow & Red								■	■	■			Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Wallum Heath	*Epacris pulchella*	Ericaceae	Woodland, Heath	1 m	White to Pink	■	■	■	■	■	■							Semi-shade	Moist well drained	●	●					●	●	●	●
Shrub / Medium	Broad-leaf Wedge Pea	*Gompholobium latifolium*	Fabaceae	Woodland, Forest	2 m	Yellow								■	■	■	■		Sun	Well drained	●	●	●	●	●	●	●	●	●	
Shrub / Medium	Hop Goodenia	*Goodenia ovata*	Goodeniaceae	Forest	1 m	Yellow										■	■	■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Silky Grevillea	*Grevillea sericea*	Proteaceae	Woodland, Forest	2 m	Pink							■	■	■	■	■		Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Grey Spider Flower	*Grevillea sphacelata*	Proteaceae	Woodland, Forest	2 m	Light Pink								■	■	■	■		Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Native Indigo	*Indigofera australis*	Fabaceae	Woodland	1.5 m	Mauve								■	■				Semi-shade	Well drained to moist	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	White Beard / Lance-leaf Beard Heath	*Leucopogon lanceolatus*	Ericaceae	Forest, Rainforest margins	2 m	White									■	■	■	■	Semi-shade	Well drained to moist	●	●			●	●	●	●	●	●
Shrub / Medium	Narrow-leaved Geebung	*Persoonia linearis*	Proteaceae	Forest, Woodland	2 m	Yellow	■	■	■	■	■	■	■					■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Slender Rice Flower	*Pimelea linifolia subsp. linoidea*	Thymelaeaceae	Forest	2 m	White								■	■	■	■		Sun to semi-shade	Well drained to moist	●	●			●				●	●
Shrub / Medium	Rough Bush Pea	*Pultenaea scabra*	Fabaceae	Open forest	1 m	Yellow & Red									■	■	■		Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Pill Flower / Ball Everlasting / White Dogwood	*Ozothamnus diosmifolius*	Asteraceae	Open forest	2 m	White	■									■	■	■	Sun to semi-shade	Moist well drained	●	●			●		●	●	●	●
Shrub / Large	Sydney Golden Wattle	*Acacia longifolia*	Fabaceae	Open forest	2–5 m	Yellow						■	■	■	■	■			Sun	Well drained	●		●	●	●	●		●	●	●
Shrub / Large	Flax Wattle	*Acacia linifolia*	Fabaceae	Open forest	2–4 m	Yellow	■	■	■	■	■								Sun	Well drained	●		●	●	●	●	●	●	●	●
Shrub / Large	Graceful Bush Pea	*Pultenaea flexilis*	Fabaceae	Open forest	3 m	Yellow								■	■	■			Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Tree / Small	Parramatta Wattle / Sydney Green Wattle	*Acacia parramattensis*	Fabaceae	Open forest , Woodland	1.2 m	Yellow	■	■								■	■	■	Sun	Well drained	●		●	●	●	●	●	●	●	●
Tree / Small	Sweet Pittosporum	*Pittosporum undulatum*	Pittosporaceae	Shaded forest, Rainforest	1.5 m	Creamy White								■	■				Sun to semi-shade	Moist well drained	●	●	●	●	●	●	●	●	●	●
Tree / Medium	Turpentine	*Syncarpia glomulifera*	Myrtaceae	Forest, Rainforest	15 m	Cream								■	■	■	■	■	Sun to semi-shade	Moist well drained	●	●	●	●	●	●	●	●	●	●
Tree / Large	Yellow Bloodwood	*Corymbia eximia*	Myrtaceae	Sandstone woodlands	20 m	Yellow, Cream										■			Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree / Large	Blue Mountains Ash	*Eucalyptus oreades*	Myrtaceae	Woodland	40 m	White, Cream	■	■											Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree / Large	Brown Stringybark	*Eucalyptus blaxlandii*	Myrtaceae	Forest	30 m	White, Cream										■	■		Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Broader Blue Mountains																														
Herb	Flannel Flower	*Actinotus helianthi*	Apiaceae	Forest, Heath	0.5–1.5 m	White, Cream	■	■	■	■						■	■	■	Sun to semi-shade	Well drained	●	●					●	●	●	●
Shrub / Prostrate	Laurel Leaf Grevillia	*Grevillea laurifolia*	Proteaceae	Open forest, Woodland	0.3 m	Red										■	■	■	Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Small	Heathy Mirbelia	*Mirbelia rubiifolia*	Fabaceae	Heath, Open woodland	0.5 m	Pink-lilac									■	■	■		Semi-shade	Moist well drained	●	●	●	●	●	●	●	●	●	
Shrub / Medium	Pale Pink Boronia	*Boronia floribunda*	Rutaceae	Open forest, Heath	1 m	Pale Pink	░								■	■	■	░	Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Sydney Boronia / Ledum Boronia	*Boronia ledifolia*	Rutaceae	Open forest, Woodland, Heath	0.3–1 m	Pink							■	■	■				Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Variable Bossiaea	*Bossiaea heterophylla*	Fabaceae	Open forest, Woodland	1 m	Yellow & Red				■	■	■	■	■					Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Hop Bitter Pea	*Daviesia latifolia*	Fabaceae	Open forest	2 m	Yellow & Red									■	■	■		Sun to semi-shade	Well drained to moist	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Gorse Bitter Pea	*Daviesia ulicifolia*	Fabaceae	Open forest	1 m	Yellow & Red								■	■	■	■		Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Sandstone Parrot Pea	*Dillwynia brunioides*	Fabaceae	Heath, Forest	1 m	Yellow & Red													Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Mountain Devil / Honey Flower	*Lambertia formosa*	Proteaceae	Open forest, Heath, Scrub	2 m	Red	■	■	■	■	■				■	■	■	■	Sun	Well drained	●	●					●	●		
Shrub / Medium	Large-fruited Tea Tree	*Leptospermum macrocarpum*	Myrtaceae	Forest, Heath	1–2 m	Pink, Red, Lemon-yellow										■	■	■	Sun to shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Medium	Hillock Bush	*Melaleuca hypericifolia*	Myrtaceae	Woodland, Heath	2–4 m	Orange, Red	■	■								■	■	■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Large	Heath Banksia	*Banksia ericifolia*	Proteaceae	Scrub, Heath	6 m	Red-orange				■	■	■	■	■					Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Large	Crimson Bottlebrush	*Callistemon citrinus*	Proteaceae	Swamp	1–2 m	Red										■	■	■	Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Large	Dagger Hakea	*Hakea teretifolia*	Proteaceae	Heath, Woodland	3 m	White	■	■	■	■									Sun	Well darined to moist	●	●	●	●	●	●	●	●	●	●
Shrub / Large	Tick Bush	*Kunzea ambigua*	Myrtaceae	Heath, Woodland, Open forest	3 m	White										░	■	■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Large	Pink Tea Tree	*Leptospermum squarrosum*	Myrtaceae	Woodland, Shrubland, Heath	3–4 m	White to Pink	■	■	■	■	■	■	■	■					Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Shrub / Large	Pine-Leaf Geebung	*Persoonia pinifolia*	Proteaceae	Forest	4 m	Yellow	■	■	■	■	■	■	■						Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree / Large	Sydney Peppermint	*Eucalyptus piperita subsp. piperita*	Myrtaceae	Woodland	25 m	White, Cream	■										■	■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree / Large	Narrow Leaf Peppermint	*Eucalyptus radiata*	Myrtaceae	Woodland	30 m	White, Cream	■									■	■	■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree / Large	Blue Mountains Mallee Ash	*Eucalyptus stricta*	Myrtaceae	Woodland	50 m	White	■	■	■	■	■							■	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●

Know your pollinators


European honey bee
(Apis mellifera) © iStock

European honey bees have two pairs of wings and long, segmented antennae. They are daytime-flying and feed on nectar and pollen. They are generalist pollinators and provide the bulk of pollination services for horticulture and crop plants. Honey bees and native bees are both essential to functioning ecosystems and food security in Australia.

Honey bees have become an important part of the Australian landscape. Honey bees live as colonies, and have a long history of coexistence with humans, including in domestic gardens.


Leafcutter bee
(Megachile maculariformis) © Karen Retra

Australian native bees comprise more than 2000 species, which provide essential pollination services. Native bees are generally solitary and live in nests in the ground or in hollow stems, old borer holes and other cracks and crevices, and some have evolved to pollinate particular native flowers through 'buzz pollination'. Although many Australian native bees are generalist foragers, some species have co-evolved with native plants and adapted to be the most effective pollinators of their flowers. Many native plant species, such as *Dianella* and *Grevillea* require specially adapted insects to access their nectar and enable the transfer of pollen to the stigma. Most native bees are solitary, but some species found in northern Australia (*Tetragonula* sp. and *Austroplebeia* sp.) are social bees and are used for commercial pollination of crops like macadamia nuts.


Bee fly
(Family *Bombyliidae*) © Karen Retra

Fly species number up to 30,000 in Australia, and can be identified by having only one pair of flight wings. A second set of wings are modified into club-shaped paddles that allow flies to hover and stabilise their flight. Unlike bees and wasps, they have very small, clubbed antennae at the front of their head. Flies, including blowflies, are often attracted to flowers that smell like carrion; they generally have hairy bodies that easily collect pollen while they are feeding. Flies provide a range of services in the garden, including pollination, decomposition and predation.


Hoverfly
(Family *Syrphidae*) © Karen Retra

Hoverflies are a type of fly, distinguishable by their large eyes, short antennae, bright black and yellow abdomen and their hovering flight behaviour. Adult hoverflies are nectar and pollen feeders. Hoverfly larvae feed on pests such as aphids, thrips and leafhoppers and are useful biocontrol agents.


Horned beetle
(Rhipicera femorata) © J. Hort

Beetles have hard outer wings that form their distinctive beetle shape. Their outer wings form a T-shape where they join at the top, unlike bugs where the outer wings make an X- or Y-shape. Beetles feed on nectar and pollen, usually by crawling over flower surfaces. There are around 30,000 species of beetles in Australia, with many yet to be formally described.


Meadow argus
(Junonia villida) © J. Hort

Butterflies have wings covered in tiny scales. They have clubbed antennae and hold their wings upright when at rest. They are day-flying and have long tongues that they can use to feed on nectar in flowers with deep tubes. Butterflies are usually brightly coloured, with approximately 600 species found in Australia.


Beautiful leaf moth
(Gastrophora henricaria) © Karen Retra

Moths also have wings covered in tiny scales and tend to be subtle in colour. They have antennae without clubs and hold their wings flat when at rest. They are generally dusk- and night-flying but there are some exceptions: the grapevine moth is a commonly seen day-flying moth. Moths feed on nectar. Australia has a high diversity of moth species, with up to 22,000 species thought to exist across the continent.

Flower forms


© Meredith Cosgrove

Generalist flowers can be pollinated by many different insects and animals. They are typically saucer shaped with many stamens and have a surface that insects can walk on. *Eucalyptus* flowers and daisy flowers are generalist flowers — they can be pollinated by bees, flies, beetles and butterflies.


© Meredith Cosgrove

Specialist flowers have modifications to their shape and size that only let certain pollinators access the nectar and pollen. These flowers might have deep flower tubes or narrow entry points so that only a select group of pollinators can access them. The advantage of specialisation is that pollination is very targeted and efficient, with accurate pollen placement made possible by co-evolution between flowers and insects. The disadvantage is that if the correct pollinator isn't there, the flowers aren't pollinated. Often, nectar is produced at the base of the flower, forcing pollinators to enter the flower fully and in the process, become covered in pollen.

Pollinator rewards

Nectar is a sugary solution, rich in carbohydrates, vitamins and minerals, produced by flowers and sometimes by glands on leaves or stems (called extra-floral nectaries). Nectar is attractive to insects, and provides an immediate energy source needed for tasks such as hunting pest insects, laying eggs in decomposing organic matter, collecting pollen, or parasitising other insects.

Carbohydrates alone don't support everything needed for health and growth, so insects also need pollen.

Pollen is rich in protein, fats and nutrients. Bees are vegetarian, and need to collect pollen to feed their offspring.

Buzz pollination

Some flowers do not produce any nectar; they specifically target pollen-collecting bees, and only offer pollen rewards. To limit pollen loss and ensure effective pollination, some plants produce flowers with specialised, tubular anthers, that only open at the tip. To extract pollen, bees use vibrations to 'buzz' the pollen grains out of the pores of these anthers. Many crops are buzz pollinated, including tomatoes, potatoes, eggplants, capsicum, chillies, tomatillo and cranberries.

European honey bees are unable to buzz pollinate flowers, but several native bees, such as the blue-banded bee, and teddy bear bee (*Amegilla* sp.) and carpenter bee (*Xylocopa* sp.) are exceptionally good large buzz pollinators, and have evolved to pollinate native plants such as flax lilies (*Dianella* sp.). Many of our smaller, ground nesting bees utilise vibration to help them excavate their burrows, and they also use that skill to buzz pollen from the anthers of native plants.

Planting buzz-pollinated species will encourage populations of buzz pollinators for successful pollination of food crops and ensure seed set in native plants. Many small ground nesting bees also buzz pollinate native flowers.

Nectar feeding

Grevillea flowers and other tubular flowers are often adapted to be successfully pollinated by birds. Pollen is 'presented' on a floral stigma that extends outside the flower. When birds feed on the nectar, pollen is deposited on their beaks or heads. Bees, also attracted to the sugary nectar, crawl into the side of the flower and feed on the nectar without encountering the pollen-laden stigma. The plant doesn't receive the pollination benefit from the insect, but flowers such Grevillea species can be a very useful source of nectar for insects in the cooler months.

Wholesale Nurseries

Most of the plants shown in the planting guide will be available at nurseries that have a good stock of native plants. But if your local nursery doesn't stock the plant you're after, ask them to order it in. For a list of wholesale nurseries that stock all the plants shown in the planting guide, plus other useful resources, visit the Wheen Bee Foundation website or scan the QR code.

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WheenBeeFoundation.org.au/our-work/powerful-pollinators

Wheen Bee Foundation

Powerful Pollinators Planting Guides are produced by Wheen Bee Foundation. We fund vital strategic research and education initiatives that strengthen bees, improve pollination efficiency, and protect our food security and ecosystem health. Visit the website for more information.

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Far left: The spreading flax lily, *Dianella revoluta,* is buzz pollinated.

Left: This European honey bee is 'side-working': feeding on the nectar-rich flowers without coming into contact with the plant's pollen.

Front cover:
1. Australian native bee, *Tetragonula carbonaria* foraging on apple blossom *(Malus domestica).* (Photo: Lisa Vella)
2. View from Govetts Leap, Blackheath, looking into the Grose Valley. (Photo: Amy-Marie Gilpin)
3. European honey bees, *Apis mellifera.* (Photo: Kirrily Hughes)

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WHEEN BEE FOUNDATION

Sydney Basin Coastal: New South Wales

Powerful pollinators

Encouraging insect pollinators in farm landscapes

Pollinators are an essential component of agricultural production and of healthy, biodiverse landscapes. Protecting and enhancing pollinator resources on farms will help support a diverse range of pollinators. This brochure provides an introduction to encouraging insect pollinators on farms, including a guide to choosing plants that will support diverse pollinators throughout the year.

WHEEN BEE FOUNDATION

The power of pollinators

Pollinators – mostly insects, but also birds and mammals – assist the formation of seeds and fruit in many plant species by visiting flowers in search of food (nectar and/or pollen). Whilst foraging they transfer pollen from one flower to another, facilitating fertilization, which results in fruits and seeds.

Honey bees, native bees and other native insects like hoverflies, wasps and butterflies provide essential pollination services for native plants, garden flowers, fruits and vegetables.

Native vegetation supports pollinators by providing food and nesting sites. Nearby crops and pastures will benefit from the increased abundance and diversity of pollinators in the landscape.

Pollinators and food security

Without insect pollinators, the quantity and diversity of food and flowers grown in backyard gardens would be severely restricted. Many of the foods we eat, from gardens and farms, benefit from pollination.

Pollinator-dependent foods include citrus, apples, stone-fruits, zucchini, pumpkins, strawberries and tomatoes, as well as plants grown for seed such as sunflowers, coriander and parsley.

The quantity and diversity of insect pollinators are key drivers of production as they influence both food yields and quality. Under-pollination results in smaller and misshapen fruit or seed that isn't viable to grow.

A diverse and healthy community of pollinators generally provides more effective and consistent pollination than relying on any single species.

Pollinators are essential to, and dependent upon, healthy ecosystems. A growing human population and increasing demand for food puts pressure on ecosystems, with potential negative impacts on biodiversity, the environment and food production.

Insect populations are in decline worldwide due to land clearing, intensive or monocultural agriculture, pesticide use, pollution, colony disease, increased urbanisation and climate change. Low pollinator numbers mean not all flowers are pollinated, leading to low fruit or seed set. This in turn reduces fruit and vegetable harvest yields, and decreases food supply.

Under-pollination results in smaller, misshapen fruit such as this strawberry.

Backyard biodiversity

Insect pollinators are a prime example of the importance of healthy ecosystems in urban gardens, parks and reserves. Insects are the 'canaries in the coal mine' of our urban and rural environments. Without our 'littlest creatures', we lack pollinators, natural beneficial pest control services, and critical food source for other insects, birds, amphibians, reptiles and mammals.

The presence of connected and widespread pollinator habitat is critical to support insect populations if we are to maintain sustainable cities and productive, healthy gardens and urban farms for food security and biodiversity.

Pollinators require habitat that contains year-round food sources, breeding resources and nesting sites. The presence of pollinator habitat adjacent to food crops has been shown to improve food production by enabling a greater variety and number of pollinators to persist year-round, providing pollination services when required.

Turn to the centre of this brochure for a guide to planting for pollinators.

Diapause or diet? Where are the insects?

Many insect pollinators undergo a diapause during colder winter months. Diapause is a period of suspended development during unfavourable environmental conditions, and during this period insect pollinators do not need flowers. Birds and other small mammals will continue to benefit from available pollen and nectar during this time.

If there are low numbers of insect pollinators in your local area, it is important to determine whether this is because of diapause, or because of an inadequate availability of nectar and pollen creating a 'food desert' where insect pollinators cannot survive.

There are still many unknowns about insect pollinators in Australia. Take part in Australian Pollinator Week or in the bi-annual Wild Pollinator Count to learn more about pollinators in your area — visit **AustralianPollinatorWeek.org.au** and **WildPollinatorCount.com**

Encouraging pollinators in your garden

Create pollination reservoirs

Pollination reservoirs are areas that provide floral resources for pollinators. They can be gardens, new planting or existing habitat such as established trees, or even local bushland, parks or reserves. A high diversity of plant species is essential to provide nectar, pollen and nesting sites throughout the year. Pollination reservoirs need to be close enough to where pollinators live to ensure that they can fly easily to them.

Improve on what you have

Enhance and improve your existing pollinator habitat where possible. Gardens that already contain established trees, rockeries, ponds, bare soil and organic matter, and a variety of flowering plants, are a valuable resource for beneficial insects and pollinators.

Nature-strips, verges, laneways, vegetable gardens, orchards, nature reserves, and riverbanks and creeks can all be important pollinator-attracting areas. Protect and enhance native pollinator plants in your garden and surrounds for the future.

Plant trees, shrubs and groundcovers

Planting a variety of species of groundcovers, shrubs and trees to in your garden will further attract pollinators to your patch. Initial watering and protection will improve the success rate of young plants. Some species such as wildflowers or native pea species are excellent pollinator attractors and reward careful attention by keen gardeners.

Be a citizen scientist and do some detective work to discover local pollinators in your patch. Visit **inaturalist.ala.org.au** to be involved.

Construct insect real estate

Insect hotels, which are both functional and attractive, are a great way to add to habitat and nesting places for pollinators and insects in your backyard or garden. The hotels are easily moved to be close to flowering plants and those needing pollination, especially if you have a new garden that is still growing. Include lots of different sized holes, cracks and crevices to provide homes for various solitary insect pollinators.

Plant for the future

When establishing pollinator habitat, consider including species that are indigenous to your area but can tolerate increasingly drier and warmer conditions, to create resilient habitat for climate change. Rehabilitate weedy areas into managed pollination reservoirs by introducing lots of flowering plant diversity. Be careful not to plant invasive or listed weeds, and look for suitable replacements.

Amplify the flower signal

Plants have evolved large flowers or clusters of smaller flowers because they attract more pollinator visits. Large, colourful and diverse plantings attract more pollinators. Ideally, plant in groups that contain different vegetation layers — combine a species-rich mixture of wildflowers, ground-covers, herbs, lilies, rushes, climbers, shrubs and trees.

Connectivity counts

Insect pollinators benefit from greater connectivity of habitat in a landscape, which allows them to forage over a wider radius and increase in numbers in a local area. Encourage friends and neighbours to plant for pollinators and create connections in your community.

Get to know your local flora

Your local government area has distinct populations of insects, depending on the local flora and environment. Knowing your local insect species will help you develop better plantings.

The plants growing in nearby nature reserves or bushland will be suited to your climate and soils. Local environment groups and specialist native nurseries can provide information about local plants.

Grow a bumper crop

Pollinator-attracting plants include many fruits and vegetables grown in backyards, community and market gardens, and orchards. Pollinators ensure good yields of crops such as apples, beans, avocado, and almonds, and bush foods such as lilly-pilly and yam daisy.

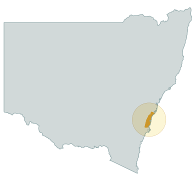
Reduce chemical use

Insecticides, fungicides and herbicides all affect bee, colony and wild pollinator health. Herbicides can impact pollinators by reducing the availability and diversity of flora and removing vegetation that helps support insect life. Some herbicides can also harm the beneficial bacteria in the insect gut. Insecticides are an obvious threat to pollinators, yet many pollinators will, in healthy numbers, help control pest insects, ultimately reducing the need for insecticide use.

Many crops are dependent on pollination by bees. When chemical pest control is unavoidable, select products that are least harmful for pollinators and apply insecticides in the evening or at night when pollinators are not active. Always use according to directions, especially for withholding periods, and notify beekeepers a few days before spraying chemicals so beehives can be safely relocated away from harm.

Safeguard the bees? The best way to 'save the bees' and protect our pollinators is to create an abundance of diverse habitat — from the ground up! There is much interest in keeping a bee hive to promote pollinators, but there are serious legal and biosecurity responsibilities that must be considered, and that the introduction of a bee hive does not displace existing native pollinators and insects. Be a friend of pollinators and say it with flowers!

A guide to planting for pollinators for the Sydney Basin Coastal region



Healthy populations of insect pollinators are important for sustainable and resilient farms, orchards, gardens, and native flora.

This Guide will help you select plant species to attract and sustain pollinators in agricultural areas and gardens throughout the year.

The eastern portion of the Sydney Basin Bioregion within New South Wales encompasses coastal subregions extending from the Illawarra to Nowra. The coastal subregions within the Sydney Basin feature vegetated cliff-faces on coastal escarpment, with waterfalls and streams. The variety of high-fertile loam soils support species-rich vegetation communities. The coast hosts mixed warm-temperate and subtropical rainforests, coastal dunes, freshwater swamps, lakes, mangroves and estuaries. It is dominated by a temperate climate characterised by warm summers with no dry season.

The plants listed in this Guide will help supply rewards to pollinators, with an emphasis on species that are indigenous and suited to local climates.

Garden centres sell many common pollinator-attracting ornamental flowers and herbs labelled as 'bee-friendly'.

The eucalypt species in this Guide are mostly large trees, and not suitable for all gardens, but have been included for their value as good nectar producing species. Most eucalypts do not flower every year, so choosing diverse species will help create continuously flowering habitat.

WHEEN BEE FOUNDATION

The pollinator plant list

To create pollinator-attracting plantings, use the Guide to choose a selection of plants with a variety of flower colours, different growth habits and a range of flowering seasons.

For each species, the planting Guide lists:

- life-form/'habit' (climber, herb, shrub or tree) and height (m).
- the vegetation type in which they naturally occur
- flower colour and flowering season
- growth requirements (sun/shade, moist/dry)
- insect groups that may visit each plant and the floral reward (pollen and/or nectar).

The coloured bars indicate the flowering months for each species. Darker shading denotes the peak flowering period, with a lighter shading for non-peak flowering months. Flowering dates may differ between regions and seasons, particularly for non-peak times, if your local climate is consistently warmer or cooler than average, with earlier or later flowering.

Sourcing plants

Most of the plant species listed are available from retail or wholesale nurseries or native plant growers, and local environment groups. If you can't source these plants at your local garden centre, or indigenous nursery, ask them to contact the local wholesale nursery suppliers and plant growers listed online. See the reverse of the Guide for details.

WheenBeeFoundation.org.au

Lifeform	Common name	Scientific name	Family	Vegetation type	Height	Flower colour	Aspect	Soil moisture	Pollinator reward: Pollen	Nectar	Visitation by pollinator: Native bees	Honey bees	Hoverflies	Wasps	Butterflies	Moths	Beetles	Flies
Climber/Forb	Creeping Bossiaea	*Bossiaea prostrata*	Fabaceae	Variable	0.6 m	Yellow, Red	Sun to semi-shade	Dry	●	●	●	●		●				
Climber/Forb	Climbing Saltbush	*Einadia nutans subsp. linifolia*	Chenopodiaceae	Variable	1 m	Green	Sun to semi-shade	Dry	●	●		●					●	●
Forb	Common Woodruff	*Asperula conferta*	Rubiaceae	Woodland, Grassland, Forest	0.3 m	White	Sun to semi-shade	Moist	●		●	●	●					●
Forb	Grass Daisy	*Brachyscome angustifolia*	Asteraceae	Swampy ground	< 0.7 m	Purple, Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●		●	
Forb	Rock Daisy	*Brachyscome multifida*	Asteraceae	Sclerophyll forest, Grassland	0.1–0.2 m	Purple, Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●		●	
Forb	Pale Grass-Lily	*Caesia parviflora*	Anthericaceae	Heath, Woodland, Dry Sclerophyll Forest	< 0.6 m	White-purple	Semi-shade to shade	Moist to dry	●		●	●	●	●	●	●	●	●
Forb	Yellow Burr-Daisy	*Calotis lappulacea*	Asteraceae	Sclerophyll woodland, grassland	< 0.5 m	Yellow	Sun to semi-shade	Moist	●		●	●	●	●	●		●	●
Forb	Billy Buttons	*Craspedia variabilis*	Asteraceae	Sclerophyll forest, Woodland, Grassland	< 0.5 m	Yellow	Sun to semi-shade	Moist	●		●	●	●					
Forb	Blue Flax-Lily	*Dianella longifolia*	Phormiaceae	Sclerophyll forest	0.8 m	Purple	Sun to semi-shade	Dry	●		●							
Forb	Nodding Chocolate Lily	*Dichopogon (Arthropodium) fimbriatus*	Anthericaceae	Sclerophyll forest, Woodland, Grassland	0.35–1 m	Purple	Sun	Moist	●		●				●			
Forb	Native Geranium	*Geranium solanderi*	Geraniaceae	Woodland, Grassland	< 0.6 m	Pink, White	Sun to semi-shade	Moist	●	●	●	●	●	●			●	●
Forb	Branched Goodenia	*Goodenia paniculata*	Goodeniaceae	Woodland, Grassland, Heathland, Swamp fringe	< 0.5 m	Yellow	Sun	Moist	●		●	●	●	●				
Forb	Small St. John's Wort	*Hypericum gramineum*	Clusiaceae	Open forest, Grassland	0.1–0.4 m	Yellow	Sun to semi-shade	Dry	●		●	●	●	●				
Forb	Native Flax	*Linum marginale*	Linaceae	Grassland, woodland, Open forest, Grassy wetland	0.1–0.6 m	Blue	Sun to semi-shade	Moist	●	●	●	●	●	●			●	●
Forb	Cockspur Flower	*Plectranthus parviflorus*	Lamiaceae	Variable	0.1–0.7 m	Blue, Purple	Sun to shade	Moist to dry	●	●	●				●	●		
Forb	Showy Copper-Wire Daisy	*Podolepis jaceoides*	Asteraceae	Woodland, Grassland	< 0.7 m	Yellow	Sun to semi-shade	Moist to dry	●		●	●	●	●				
Forb	Matted Pratia	*Pratia pedunculata*	Lobeliaceae	Wet sclerophyll forest	< 0.2 m	White	Sun to light shade	Moist to dry	●	●	●				●		●	
Forb	Pastel Flower	*Pseuderanthemum variabile*	Acanthaceae	Rainforest, Wet sclerophyll forest	0.15–0.3 m	White, Mauve	Sun to light shade	Moist	●	●	●				●		●	
Forb	Chamomile Sunray	*Rhodanthe anthemoides*	Asteraceae	Open forest, Grassland	0.15–0.3 m	White, Yellow	Sun	Dry	●	●	●	●	●	●	●	●	●	●
Forb	Swamp Dock	*Rumex brownii*	Polygonaceae	Woodland, disturbed habitat	0.5–0.8 m	Green, Red	Sun to semi-shade	Dry	●	●							●	●
Forb	Purple Fan Flower	*Scaevola aemula*	Goodeniaceae	Dry sclerophyll forest	< 0.5 m	Purple, Yellow	Sun to semi-shade	Dry	●	●	●	●	●	●			●	●
Forb	Forest Nightshade	*Solanum prinophyllum*	Solanaceae	Sclerophyll forest	< 0.5 m	Purple	Semi-shade	Moist	●*	●	●							
Forb	Native Violet	*Viola hederacea*	Violaceae	Woodland, Forest	0.1–0.2 m	White, Purple, Mauve	Semi-shade to shade	Moist	●	●	●	●						●
Grass	Basket Grass	*Oplismenus imbecillis*	Poaceae	Shady forest	< 0.3 m	Green, Pink	Semi-shade to shade	Moist	●	●								●
Tussock Grass	Weeping Grass	*Microlaena stipoides*	Poaceae	Widespread	< 0.7 m	Green	Sun to semi-shade	Moist to dry	●								●	●
Tussock Grass	Kangaroo Grass	*Themeda triandra*	Poaceae	Variable	< 1.2 m	Green, Brown	Sun to semi-shade	Moist to dry	●								●	●
Vine	Wombat Berry	*Eustrephus latifolius*	Luzuriagaceae	Sclerophyll forest, Woodland, Heath	Climber	Cream, Pink	Sun to semi-shade	Moist to dry	●	●					●	●	●	●
Vine	Sweet Morinda	*Gynochthodes jasminoides*	Rubiaceae	Sclerophyll forest, Rainforest	Climber	White	Semi-shade to shade	Moist to dry	●	●	●	●	●	●			●	●
Vine	Dusky Coral Pea	*Kennedia rubicunda*	Fabaceae	Variable	Climber	Red	Sun	Dry	●	●	●	●						●
Vine	Bower of Beauty	*Pandorea jasminoides*	Bignoniaceae	Rainforest	Climber	Pink	Sun to semi-shade	Moist to dry	●	●	●	●		●	●	●		
Palm & palmlike	Cabbage-tree Palm	*Livistona australis*	Arecaceae	Rainforest margins, Moist sclerophyll forest	< 30 m	Yellow	Sun to shade	Moist to dry	●		●	●	●	●				
Shrub	Wattle	*Acacia longifolia*	Fabaceae	Dry Sclerophyll Forest, Woodland, Heath	3–10 m	Yellow	Sun to semi-shade	Dry	●		●	●	●	●	●	●	●	●
Shrub	White Aspen	*Acronychia oblongifolia*	Rutaceae	Rainforest margins, Moist sclerophyll forest	< 2.7 m	White	Sun to semi-shade	Moist	●	●	●	●	●	●			●	●
Shrub	Grey Myrtle	*Backhousia myrtifolia*	Myrtaceae	Warm rainforest	3–4 m	White	Sun to semi-shade	Dry	●	●	●	●	●	●	●	●	●	●
Shrub	Coffee Bush	*Breynia oblongifolia*	Phyllanthaceae	Warm rainforest, Woodland, Eucalypt forest	< 3 m	Red, Green	Sun to semi-shade	Dry	●	●					●	●	●	
Shrub	White Paper Daisy	*Coronidium elatum*	Asteraceae	Eucalypt forest	< 2 m	White, Yellow	Sun	Dry	●	●	●	●	●	●	●	●	●	●
Shrub	Gorse Bitter Pea	*Daviesia ulicifolia*	Fabaceae	Open forest	1 m	Yellow & red	Sun to semi-shade	Dry	●	●	●	●	●	●				●
Shrub	Sieber's Parrot-Pea	*Dillwynia sieberi*	Fabaceae	Dry Sclerophyll Forest, Woodland	0.50-2.5 m	Yellow	Semi-shade	Dry	●	●	●	●	●	●				●
Shrub	Blueberry Ash	*Elaeocarpus reticulatus*	Elaeocarpaceae	Tall Eucalypt forest, near Rainforest	4–10 m	White, Pink	Sun to semi-shade	Moist to dry	●	●	●	●	●				●	●
Shrub	Winter Apple	*Eremophila debilis*	Myoporaceae	Woodland	< 0.5 m	Blue, Pink or Mauve	Sun	Dry	●	●	●	●		●				●
Shrub	Hop Goodenia	*Goodenia ovata*	Goodeniaceae	Woodland, Forest	1–1.5 m	Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●				●
Shrub	Hoary Guinea Flower	*Hibbertia obtusifolia*	Dilleniaceae	Variable	< 0.6 m	Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●				●
Shrub	Native Indigo	*Indigofera australis*	Fabaceae	Woodland	1.5 m	Mauve	Semi-shade	Moist to dry	●	●	●	●	●	●	●	●	●	●
Shrub	Tea-tree	*Leptospermum morrisonii*	Myrtaceae	Sclerophyll woodland, shrubby communities	2–5 m	White	Sun to semi-shade	Moist to dry	●	●	●	●			●		●	●
Shrub	White Feather Honeymyrtle	*Melaleuca decora*	Myrtaceae	Swampy ground	< 7 m	White	Sun to semi-shade	Moist	●	●	●	●	●	●			●	●
Shrub	Prickly-leaved Tea Tree	*Melaleuca styphelioides*	Myrtaceae	Moist environments	< 20 m	White	Sun to semi-shade	Moist to dry	●	●	●	●	●	●			●	●
Shrub	Veined Mock-olive	*Notelaea venosa*	Oleaceae	Rainforest, Wet sclerophyll forest	< 10 m	Cream, Yellow, Green	Semi-shade	Moist to dry	●	●	●	●	●	●			●	●
Shrub	Toothed Daisy-bush	*Olearia tomentosa*	Asteraceae	Dry sclerophyll forest, Heath	< 2 m	Purple, Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●			●	●
Shrub	Orange Thorn	*Pittosporum multiflorum*	Pittosporaceae	Rainforest, Wet sclerophyll forest	1–3 m	White	Semi-shade to shade	Moist	●	●	●	●		●	●		●	●
Shrub	Native Daphne	*Pittosporum undulatum*	Pittosporaceae	Rainforest, Wet sclerophyll forest	< 15 m	Cream	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●		●	●
Shrub	Wedding Bush	*Ricinocarpos pinifolius*	Euphorbiaceae	Coastal	1–2 m	White	Light shade	Dry	●	●	●	●	●	●	●		●	●
Shrub	Scentless Rosewood	*Synoum glandulosum*	Meliaceae	Warm rainforest	< 7 m	White	Semi-shade to shade	Dry	●	●	●	●	●	●			●	●
Shrub	Coastal Rosemary	*Westringia fruticosa*	Lamiaceae	Coastal	1.5–2 m	White, Mauve	Sun to semi-shade	Dry	●	●	●	●	●	●	●		●	●
Shrub	Sandfly Zieria	*Zieria smithii*	Rutaceae	Variable	< 2 m	White	Light shade	Moist to dry	●	●	●	●	●	●			●	●
Tree	Drooping Sheoak	*Allocasuarina verticillata*	Casuarinaceae	Grassy woodland	5–10 m	Yellow, Red	Sun to semi-shade	Dry	●		●	●		●				
Tree	Coast Banksia	*Banksia integrifolia*	Proteaceae	Coastal	4–15 m	Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●		●	●
Tree	Old Man Banksia	*Banksia serrata*	Proteaceae	Dry sclerophyll forest, Woodland	3–15 m	Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●		●	●
Tree	Illawarra Flame Tree	*Brachychiton acerifolius*	Malvaceae	Subtropical rainforest	< 35 m	Red	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●		●	●
Tree	Hairy Clerodendrum	*Clerodendrum tomentosum*	Lamiaceae	Rainforest margins	1–10 m	Cream	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●	●	●	●
Tree	Bangalay	*Eucalyptus botryoides*	Myrtaceae	Dry sclerophyll forest, Woodland	< 40 m	White	Sun to semi-shade	Dry	●	●	●	●	●	●	●	●	●	●
Tree	Blackbutt	*Eucalyptus pilularis*	Myrtaceae	Wet sclerophyll forest, Grassy coastal forest	< 70 m	White	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●	●	●	●
Tree	Sydney Blue Gum	*Eucalyptus saligna*	Myrtaceae	Widespread	< 50 m	Cream	Sun to semi-shade	Dry	●	●	●	●	●	●	●	●	●	●
Tree	Forest Red Gum	*Eucalyptus tereticornis*	Myrtaceae	Wet & dry sclerophyll forest, Woodland	< 50 m	Cream	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●	●	●	●
Tree	Snow Wood	*Pararchidendron pruinosum*	Fabaceae	Rainforest, Riverine forest	< 15 m	Cream, Yellow	Sun	Moist to dry	●	●	●	●	●	●			●	●
Tree	Turpentine Tree	*Syncarpia glomulifera*	Myrtaceae	Forest, Rainforest	< 15 m	Cream	Sun to semi-shade	Moist to dry	●	●	●	●	●	●	●	●	●	●
Tree	Lilly Pilly	*Syzygium smithii*	Myrtaceae	Rainforest	3–5 m	Cream	Sun to semi-shade	Moist to dry	●	●	●	●	●	●			●	●
Tree	Water Gum	*Tristaniopsis laurina*	Myrtaceae	Rainforest, Wet sclerophyll forest	3–6 m	Yellow	Sun to semi-shade	Moist to dry	●	●	●	●	●	●				

*Buzz Pollinated

Know your pollinators

European honey bee
(Apis mellifera) © iStock

European honey bees have two pairs of wings and long, segmented antennae. They are daytime-flying and feed on nectar and pollen. They are generalist pollinators and provide the bulk of pollination services for horticulture and crop plants. Honey bees and native bees are both essential to functioning ecosystems and food security in Australia.

Honey bees have become an important part of the Australian landscape. Honey bees live as colonies, and have a long history of coexistence with humans, including in domestic gardens.

Leafcutter bee
(Megachile maculariformis) © Karen Retra

Australian native bees comprise more than 2000 species, which provide essential pollination services. Native bees are generally solitary and live in nests in the ground or in hollow stems, old borer holes and other cracks and crevices, and some have evolved to pollinate particular native flowers through 'buzz pollination'. Although many Australian native bees are generalist foragers, some species have co-evolved with native plants and adapted to be the most effective pollinators of their flowers. Many native plant species, such as *Dianella* and *Grevillea* require specially adapted insects to access their nectar and enable the transfer of pollen to the stigma. Most native bees are solitary, but some species found in northern Australia (*Tetragonula* sp. and *Austroplebeia* sp.) are social bees and are used for commercial pollination of crops like macadamia nuts.

Bee fly
(Family *Bombyliidae*) © Karen Retra

Fly species number up to 30,000 in Australia, and can be identified by having only one pair of flight wings. A second set of wings are modified into club-shaped paddles that allow flies to hover and stabilise their flight. Unlike bees and wasps, they have very small, clubbed antennae at the front of their head. Flies, including blowflies, are often attracted to flowers that smell like carrion; they generally have hairy bodies that easily collect pollen while they are feeding. Flies provide a range of services in the garden, including pollination, decomposition and predation.

Hoverfly
(Family *Syrphidae*) © Karen Retra

Hoverflies are a type of fly, distinguishable by their large eyes, short antennae, bright black and yellow abdomen and their hovering flight behaviour. Adult hoverflies are nectar and pollen feeders. Hoverfly larvae feed on pests such as aphids, thrips and leafhoppers and are useful biocontrol agents.

Horned beetle
(Rhipicera femorata) © J. Hort

Beetles have hard outer wings that form their distinctive beetle shape. Their outer wings form a T-shape where they join at the top, unlike bugs where the outer wings make an X- or Y-shape. Beetles feed on nectar and pollen, usually by crawling over flower surfaces. There are around 30,000 species of beetles in Australia, with many yet to be formally described.

Meadow argus
(Junonia villida) © J. Hort

Butterflies have wings covered in tiny scales. They have clubbed antennae and hold their wings upright when at rest. They are day-flying and have long tongues that they can use to feed on nectar in flowers with deep tubes. Butterflies are usually brightly coloured, with approximately 600 species found in Australia.

Beautiful leaf moth
(Gastrophora henricaria) © Karen Retra

Moths also have wings covered in tiny scales and tend to be subtle in colour. They have antennae without clubs and hold their wings flat when at rest. They are generally dusk- and night-flying but there are some exceptions: the grapevine moth is a commonly seen day-flying moth. Moths feed on nectar. Australia has a high diversity of moth species, with up to 22,000 species thought to exist across the continent.

Flower forms

© Meredith Cosgrove

Generalist flowers can be pollinated by many different insects and animals. They are typically saucer shaped with many stamens and have a surface that insects can walk on. *Eucalyptus* flowers and daisy flowers are generalist flowers — they can be pollinated by bees, flies, beetles and butterflies.

© Meredith Cosgrove

Specialist flowers have modifications to their shape and size that only let certain pollinators access the nectar and pollen. These flowers might have deep flower tubes or narrow entry points so that only a select group of pollinators can access them. The advantage of specialisation is that pollination is very targeted and efficient, with accurate pollen placement made possible by co-evolution between flowers and insects. The disadvantage is that if the correct pollinator isn't there, the flowers aren't pollinated. Often, nectar is produced at the base of the flower, forcing pollinators to enter the flower fully and in the process, become covered in pollen.

Pollinator rewards

Nectar is a sugary solution, rich in carbohydrates, vitamins and minerals, produced by flowers and sometimes by glands on leaves or stems (called extra-floral nectaries). Nectar is attractive to insects, and provides an immediate energy source needed for tasks such as hunting pest insects, laying eggs in decomposing organic matter, collecting pollen, or parasitising other insects.

Carbohydrates alone don't support everything needed for health and growth, so insects also need pollen.

Pollen is rich in protein, fats and nutrients. Bees are vegetarian, and need to collect pollen to feed their offspring.

Buzz pollination

Some flowers do not produce any nectar; they specifically target pollen-collecting bees, and only offer pollen rewards. To limit pollen loss and ensure effective pollination, some plants produce flowers with specialised, tubular anthers, that only open at the tip. To extract pollen, bees use vibrations to 'buzz' the pollen grains out of the pores of these anthers. Many crops are buzz pollinated, including tomatoes, potatoes, eggplants, capsicum, chillies, tomatillo and cranberries.

European honey bees are unable to buzz pollinate flowers, but several native bees, such as the blue-banded bee, and teddy bear bee (*Amegilla* sp.) and carpenter bee (*Xylocopa* sp.) are exceptionally good large buzz pollinators, and have evolved to pollinate native plants such as flax lilies (*Dianella* sp.). Many of our smaller, ground nesting bees utilise vibration to help them excavate their burrows, and they also use that skill to buzz pollen from the anthers of native plants.

Planting buzz-pollinated species will encourage populations of buzz pollinators for successful pollination of food crops and ensure seed set in native plants. Many small ground nesting bees also buzz pollinate native flowers.

Nectar feeding

Grevillea flowers and other tubular flowers are often adapted to be successfully pollinated by birds. Pollen is 'presented' on a floral stigma that extends outside the flower. When birds feed on the nectar, pollen is deposited on their beaks or heads. Bees, also attracted to the sugary nectar, crawl into the side of the flower and feed on the nectar without encountering the pollen-laden stigma. The plant doesn't receive the pollination benefit from the insect, but flowers such Grevillea species can be a very useful source of nectar for insects in the cooler months.

Wholesale Nurseries

Most of the plants shown in the planting guide will be available at nurseries that have a good stock of native plants. But if your local nursery doesn't stock the plant you're after, ask them to order it in. For a list of wholesale nurseries that stock all the plants shown in the planting guide, plus other useful resources, visit the Wheen Bee Foundation website or scan the QR code.

SCAN ME

WheenBeeFoundation.org.au/our-work/powerful-pollinators

Wheen Bee Foundation

Powerful Pollinators Planting Guides are produced by Wheen Bee Foundation. We fund vital strategic research and education initiatives that strengthen bees, improve pollination efficiency, and protect our food security and ecosystem health. Visit the website for more information.

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Far left: The spreading flax lily, *Dianella revoluta,* is buzz pollinated.

Left: This European honey bee is 'side-working': feeding on the nectar-rich flowers without coming into contact with the plant's pollen.

Front cover:
1. *Austroscolia soror* on *Backhousia citriodora.* (Photo: Amy-Marie Gilpin)
2. Illawarra escarpment, NSW. (Photo: Laura Lopresti)
3. European honey bees, *Apis mellifera.* (Photo: Kirrily Hughes)

Proudly funded by the NSW Government in association with Western Sydney University and Hort Innovation.

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WHEEN BEE FOUNDATION

Sydney Basin Inland: New South Wales

Powerful pollinators

Encouraging insect pollinators in rural and urban landscapes

Pollinators are an essential component of healthy, biodiverse landscapes and provide critical pollination services to native flora and agriculture production across the country.

This guide provides information on ways to encourage a diverse range of insect pollinators across all properties, and includes a planting calendar to help select plants to support diverse pollinators throughout the year.

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The power of pollinators

Pollinators – mostly insects, but also birds and mammals – assist the production of seeds and fruit in many plant species by visiting flowers in search of food (nectar and/or pollen). Whilst foraging they transfer pollen from one flower to another, facilitating fertilisation, which results in fruits and seeds.

Honey bees, native bees and other native insects like hoverflies, wasps and butterflies provide essential pollination services for native plants, pastures, crops, fruits and vegetables.

Native vegetation supports pollinators by providing food and nesting sites. Nearby crops and pastures will benefit from the increased abundance and diversity of pollinators in the landscape.

Pollinators and food security

Without insect pollinators, the quantity and diversity of food grown for humans in contemporary agricultural systems would be severely restricted. Many of the food crops we eat, as well as pasture and fodder crops, benefit from pollination by insects.

Pollinator-dependent crops include oranges, apples, berries and vegetables, as well as many crops grown for seed production, such as canola.

The quantity and diversity of insect pollinators are key drivers of production as they influence both crop yields and quality. Under-pollination results in smaller and misshapen fruit or seed that isn't viable.

Grazing enterprises can also suffer from a reduction in the abundance or diversity of pollinators, due to the role these insects play in the persistence of nitrogen-fixing pasture legumes such as clover.

A diverse and healthy community of pollinators generally provides more effective and consistent pollination than relying on any single species.

Insect populations are in decline worldwide due to land clearing, intensive or monocultural agriculture, pesticide use, pollution, colony disease, increased urbanisation and climate change. Low pollinator numbers mean not all flowers are pollinated, leading to low fruit or seed set. This in turn reduces fruit and vegetable harvest yields, and decreases food supply.

Under-pollination results in smaller, misshapen fruit such as this strawberry.

Healthy ecosystems

Pollinators are both essential to, and depend upon, healthy ecosystems. A growing human population and increasing demand for food puts pressure on ecosystems, while declining ecosystem function will in turn negatively impact food production.

Insect pollinators are a prime example of this — without healthy ecosystems and the presence of patches of native vegetation to support insect populations, pollination will decline. This will threaten both crop productivity and the persistence of native, pollinator-dependent flowering plants.

Pollinators require habitat that contains year-round food sources, breeding resources and nesting sites. The presence of pollinator habitat adjacent to food crops has been shown to improve food production by enabling a greater variety and number of pollinators to persist year-round, providing pollination services when required.

Turn to the centre of this brochure for a guide to planting for pollinators.

Diapause or diet? Where are the insects?

Many insect pollinators undergo a diapause during colder winter months. Diapause is a period of suspended development during unfavourable environmental conditions, and during this period insect pollinators do not need flowers. Birds and other small mammals will continue to benefit from available pollen and nectar during this time.

If there are low numbers of insect pollinators in your local area, it is important to determine whether this is because of diapause, or because of an inadequate availability of nectar and pollen, creating a 'food desert' where insect pollinators cannot survive.

There are still many unknowns about insect pollinators in Australia. Take part in Australian Pollinator Week or in the annual Australian Pollinator Count to learn more about pollinators in your area – visit: **AustralianPollinatorWeek.org.au** and **AustralianPollinatorCount.au**

Encouraging pollinators on your property

Create pollination reservoirs

Pollination reservoirs are areas of native plant species that provide floral resources for pollinators. They can be new plantings or existing habitat, such as shelterbelts or remnant vegetation. A high diversity of plant species is essential to provide nectar, pollen and nesting sites throughout the year. Pollination reservoirs need to be close enough to crops to ensure that pollinators can fly easily to them.

Use existing habitat

Protect and improve existing habitat where possible. Roadsides, shelterbelts, dam margins, woodlands, grasslands, rocky areas, river and creek edges can all be important pollinator-attracting areas, bringing valuable pollination services to your property.

Native vegetation stands provide habitat for pollinators, and special attention should be paid to enhance and protect these areas.

Get to know your local flora

Each property and region will have distinct populations of insects, based on the plants and climate. Identifying and understanding the insects in your area will help you develop better plantings.

The plants growing in nearby bush will be well suited to the climate and soils in your region. Local community groups and specialist native nurseries can provide useful information and usually produce local plant species.

Plant trees, shrubs and groundcovers

Planting a variety of species of groundcovers, shrubs and trees on your property will further attract pollinators to your area. Use a combination of direct seed sowing and planting tube stock to establish new vegetation. Initial watering and protection from grazing will improve the success rate of young plants. Wildflowers, including our native pea species, are excellent at attracting a diverse range of native pollinators.

Connectivity counts

Insect pollinators benefit from greater connectivity of habitat in a landscape, which allows them to forage over a wider radius and increase in numbers in a local area. Encourage neighbours and other landholders to plant for pollinators and create connections across your landscape.

Utilise ecotones

Ecotones are the margins between two different habitats. Ecotones often contain a more diverse mixture of pollinator species because they are inhabited by pollinators from both habitats. Protect and utilise ecotones such as the transition zones between woodland and grassland, or heath and shrubland, to create highly diverse floral and insect communities.

Amplify the flower signal

Plants have evolved large flowers or clusters of smaller flowers which attract more pollinator visits. Large, colourful and diverse plantings attract more pollinators. Ideally, plant in groups that contain different vegetation layers — combine a species-rich mixture of wildflowers, groundcovers, herbs, lilies, rushes, climbers, shrubs and trees.

Plant for the future

When establishing pollinator habitat, consider including species that are indigenous to your area and can tolerate increasingly warmer and drier (or wetter) conditions, to improve resilience to climate change. Rehabilitate weedy areas into managed pollination reservoirs by introducing lots of flowering plant diversity.

Be careful not to plant invasive or listed weeds, and look for suitable replacements.

Double the crop value

Plants that are pollinator-attracting may be commercially viable crop species in their own right and can be used to diversify farm production. Bush foods such as Acacia seed, Apple Berry, Native Cherry and many more are in high demand for use in fresh and manufactured products. Native plant seed is also needed for revegetation projects. Farmers can also support beekeepers by hosting beehives to increase pollinator numbers on a farm.

Reduce chemical use

Insecticides, fungicides and herbicides all affect the health of bees, bee colonies and native pollinators. Herbicides can impact pollinators by reducing the availability and diversity of flora and removing vegetation that helps support insect life. Some herbicides can also harm the beneficial microbes in the insect gut. In many circumstances, beneficial insects will, in healthy numbers, help control pest insects, ultimately reducing the need for insecticide use.

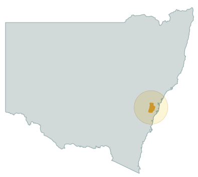
When chemical pest control is unavoidable, select products that are least harmful for pollinators and apply insecticides in the evening or at night when pollinators are not active.

Always use according to directions, especially for withholding periods, and notify beekeepers a few days before spraying chemicals so beehives can be safely relocated away from harm.

Be a citizen scientist and do some detective work to discover local pollinators on your property. Visit **inaturalist.ala.org.au** to be involved.

Safeguard the bees? The best way to 'save the bees' and protect our pollinators is to create an abundance of diverse habitat — from the ground up! There is much interest in keeping a beehive to promote pollinators, but there are serious legal and biosecurity responsibilities that must be considered, and that the introduction of a beehive does not displace existing native pollinators and insects. Be a friend of pollinators and say it with flowers!

A guide to planting for pollinators for the Sydney Basin Inland region



Healthy populations of insect pollinators are important for crop yields, orchard production and thriving native vegetation.

This planting guide will help you choose plant species to attract and keep pollinators on your property throughout the year.

The inland region of the Sydney Basin encompasses the towns of Liverpool, Bringelly and Richmond. This region is characterised by shale, sandstone, volcanic vents and alluvium soils along the rivers. Due to the variety of rock types, topography and climate the area has some of the highest levels of species diversity in Australia. This region is dominated by the Endangered Ecological Community the Cumberland Plain Woodland which is under threat due to land clearing and degradation as a direct result of the region supporting the majority of the Greater Sydney population. The climate is temperate with summer dominant rainfall throughout December–March, however there is considerable inter annual variability in precipitation.

The plants listed in this Guide will help supply rewards to pollinators, with an emphasis on species that are indigenous and suited to local climates.

The eucalypt species in the chart have been selected as high quality honey production species. Most eucalypts do not flower every year, so choosing diverse species will help create continuously flowering habitat.

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The pollinator plant list

To create pollinator-attracting plantings, use the Guide to choose a selection of plants with a variety of flower colours, different growth habits and a range of flowering seasons.

For each species, the planting Guide lists:

- life-form/'habit' (climber, herb, shrub or tree) and height (m).
- the vegetation type in which they naturally occur
- flower colour and flowering season
- growth requirements (sun/shade, moist/dry)
- insect groups that may visit each plant and the floral reward (pollen and/or nectar).

The coloured bars indicate the flowering months for each species. Darker shading denotes the peak flowering period, with a lighter shading for non-peak flowering months. Flowering dates may differ between regions and seasons, particularly for non-peak times, if your local climate is consistently warmer or cooler than average, with earlier or later flowering.

Sourcing plants

Most of the plant species listed are available from retail or wholesale nurseries or native plant growers, and local environment groups. If you can't source these plants at your local garden centre, or indigenous nursery, ask them to contact the local nursery suppliers and plant growers listed online. See the reverse of the Guide for details.

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Lifeform	Common name	Scientific name	Family	Vegetation type	Height	Flower colour	Aspect	Soil moisture	Pollinator reward: Pollen	Pollinator reward: Nectar	Visitation by pollinator: Native bees	Honey bees	Hoverflies	Wasps	Butterflies	Moths	Beetles	Flies
Crop plants																		
Tree	Orange	*Citrus × sinensis*	Rutaceae	Horticulture	< 10 m	White	Sun	Moist, Well-drained	●	●	●	●	●	●	●	●	●	●
Vine	Watermelon	*Citrullus lanatus*	Cucurbitaceae	Horticulture	< 0.6 m	Yellow	Sun	Moist, Well-drained	●	●	●	●	●				●	●
Herb / Forb	Strawberry	*Fragaria ananassa*	Rosaceae	Horticulture	0.1–0.3 m	White	Sun	Moist, Well-drained	●	●	●	●	●				●	●
Tree	Apple	*Malus domestica*	Rosaceae	Horticulture	1.5–10 m	White, Pink	Sun	Moist, Well-drained	●	●	●	●	●				●	●
Indigenous plants																		
Climber / Forb	Creeping Bossiaea	*Bossiaea prostrata*	Fabaceae	Variable	0.6 m	Yellow, Red	Sun to semi-shade	Well-drained	●	●	●	●		●				
Climber / Forb	Climbing Saltbush	*Einadia nutans* subsp. *linifolia*	Chenopodiaceae	Variable	1 m	Green	Sun to semi-shade	Well-drained	●	●		●					●	●
Climber / Forb	Spreading Nut-Heads	*Sphaeromorphaea australis*	Asteraceae	Eucalypt Forest, Saline habitat	0.3 m	Pink, Purple, Red	Sun to semi-shade	Moist	●		●	●	●	●			●	●
Vine	Small-Leaf Glycine	*Glycine microphylla*	Fabaceae	Variable	Climber	Purple	Semi to full-shade	Moist	●	●	●	●					●	●
Vine	Slender Bindweed	*Polymeria calycina*	Convolvulaceae	Grassy Woodland, Forest	Climber	Pink	Sun to semi-shade	Moist, Well-drained	●	●					●	●		
Herb / Forb	Austral Bugle	*Ajuga australis*	Lamiaceae	Rocky areas, Forest, Woodland	0.4 m	Blue, Purple	Sun to semi-shade	Dry, Sandy-soils	●	●	●	●		●	●	●		
Herb / Forb	Nodding Chocolate Lily	*Arthropodium fimbriatum*	Asparagaceae	Grass & Woodland, Forest	0.35–1 m	Purple	Sun	Moist, Well-drained	●		●				●			
Herb / Forb	Pale Vanilla Lily	*Arthropodium* sp.	Asparagaceae	Variable	0.2–1 m	White, Pink	Full-sun to full-shade	Well-drained	●	●	●	●	●			●	●	
Herb / Forb	Common Woodruff	*Asperula conferta*	Rubiaceae	Grass & Woodland, Forest	0.3 m	White	Sun to semi-shade	Moist, Well-drained	●		●	●	●					●
Herb / Forb	Pale Grass-Lily	*Caesia parviflora*	Asphodelaceae	Heath, Woodland, Forest	< 0.6 m	White, Purple	Semi to full-shade	Well-drained	●		●	●	●	●	●	●	●	●
Herb / Forb	Purple Burr-Daisy	*Calotis cuneifolia*	Asteraceae	Variable	< 0.6 m	Purple	Sun to semi-shade	Variable	●		●	●	●	●	●		●	●
Herb / Forb	Yellow Burr-Daisy	*Calotis lappulacea*	Asteraceae	Grass & Woodland	< 0.5 m	Yellow	Sun to semi-shade	Variable, Moist	●		●	●	●	●	●		●	●
Herb / Forb	Cockspur Flower	*Coleus australis*	Lamiaceae	Variable	0.1–0.7 m	Blue, Purple	Full-sun to full-shade	Variable	●	●	●				●	●		
Herb / Forb	Billy Button	*Craspedia variabilis*	Asteraceae	Grass & Woodland, Forest	< 0.5 m	Yellow	Sun to semi-shade	Moist, Well-drained	●		●	●	●					
Herb / Forb	Blue Flax-Lily	*Dianella longifolia*	Asphodelaceae	Sclerophyll forest	0.8 m	Purple, Yellow	Sun to semi-shade	Well drained	●		●							
Herb / Forb	Star Cudweed	*Euchiton involucratus*	Asteraceae	Forest, Woodland	0.15–0.5 m	Brown	Sun to semi-shade	Moist, Well-drained	●								●	●
Herb / Forb	Native Geranium	*Geranium solanderi*	Geraniaceae	Woodland, Grassland	< 0.6 m	Pink, White	Sun to semi-shade	Variable, Moist	●	●	●	●	●	●			●	●
Herb / Forb	Branched Goodenia	*Goodenia paniculata*	Goodeniaceae	Swampy Grass, Heath & Woodland	< 0.5 m	Yellow	Sun	Moist	●		●	●	●	●				
Herb / Forb	Small St. John's Wort	*Hypericum gramineum*	Hypericaceae	Open forest, Grassland	0.1–0.4 m	Yellow	Sun to semi-shade	Well-drained	●		●	●	●	●				
Herb / Forb	Native Flax	*Linum marginale*	Linaceae	Grass & Woodlands, Open Forest	0.1–0.6 m	Blue	Sun to semi-shade	Moist, Well-drained	●	●	●	●	●	●			●	●
Herb / Forb	Showy Copper-Wire Daisy	*Podolepis jaceoides*	Asteraceae	Grass & Woodland	< 0.7 m	Yellow	Semi to full-shade	Moist, Well-drained	●		●	●	●	●				
Herb / Forb	Pomax	*Pomax umbellata*	Rubiaceae	Woodland, Forest	< 0.4 m	Red	Semi to full-shade	Well drained	●	●	●		●					●
Herb / Forb	Common Buttercup	*Ranunculus lappaceus*	Ranunculaceae	Woodland, Grassland	0.15–0.4 m	Yellow	Sun to semi-shade	Moist, Well-drained	●	●	●	●	●	●				
Herb / Forb	Chamomile Sunray	*Rhodanthe anthemoides*	Asteraceae	Open forest, Grassland	0.15–0.3 m	White, Yellow	Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Herb / Forb	Swamp Dock	*Rumex brownii*	Polygonaceae	Woodland, disturbed habitat	0.5–0.8 m	Green, Red	Sun to semi-shade	Well drained	●	●							●	●
Herb / Forb	Forest Nightshade	*Solanum prinophyllum*	Solanaceae	Sclerophyll forest	< 0.5 m	Purple	Semi-shade	Moist	●	●	●							
Herb / Forb	Creamy Candles	*Stackhousia monogyna*	Celastraceae	Grass, Heath & Woodland, Forest	< 0.7 m	Cream, Yellow	Semi-shade	Well drained	●	●	●	●	●	●			●	●
Herb / Forb	Native Violet	*Viola hederacea*	Violaceae	Woodland, Forest	0.1–0.2 m	White, Purple, Mauve	Semi to full-shade	Moist	●	●	●	●						●
Herb / Forb	Fuzzweed	*Vittadinia* sp.	Asteraceae	Variable	0.1–0.4 m	Blue, Mauve	Sun	Well drained	●	●	●	●			●	●		
Herb / Forb	Bluebells	*Wahlenbergia* sp.	Campanulaceae	Grass & Woodland	0.3–0.4 m	Blue, Purple	Sun to semi-shade	Moist, Well-drained	●	●	●	●		●	●			
Herb / Forb	Common Rush	*Juncus usitatus*	Juncaceae	Stream banks	< 1 m	Brown	Sun to semi-shade	Moist	●		●			●			●	●
Herb / Forb	Wattle Mat-Rush	*Lomandra filiformis*	Asparagaceae	Dry Sclerophyll Forest	< 0.5 m	Green, Yellow	Sun to semi-shade	Well drained	●		●	●					●	●
Herb / Forb	Small Grass Tree	*Xanthorrhoea minor*	Asphodelaceae	Heath & Woodland	< 0.3 m	White, Cream	Sun to semi-shade	Well drained	●	●	●	●			●		●	●
Sedge	Knob Sedge	*Carex inversa*	Cyperaceae	Grassland, Open forest	0.2 m	Brown	Sun	Moist	●			●						●
Tussock Grass	Weeping Grass	*Microlaena stipoides*	Poaceae	Widespread	< 0.7 m	Green	Sun to semi-shade	Variable	●		●						●	●
Tussock Grass	Two-Colour Panic	*Panicum simile*	Poaceae	Woodland	< 0.7 m	Purple, Green	Sun	Moist	●		●						●	●
Tussock Grass	Tussock Grass	*Poa labillardierei*	Poaceae	Open forest, Grassy woodland	< 1.2 m	Green, Brown	Sun	Moist	●		●						●	●
Tussock Grass	Bue Tussock Grass	*Poa sieberiana*	Poaceae	Variable	< 1 m	Green, Brown	Sun to semi-shade	Variable	●		●						●	●
Tussock Grass	Wild Sorghum	*Sorghum leiocladum*	Poaceae	Woodland	< 1 m	Brown	Sun to semi-shade	Dry	●		●						●	●
Tussock Grass	Kangaroo Grass	*Themeda triandra*	Poaceae	Variable	< 1.2 m	Green, Brown	Sun to semi-shade	Variable	●		●						●	●
Shrub	Hairpin Banksia	*Banksia spinulosa*	Proteaceae	Heath & Woodland, Forest	< 3 m	Orange, Yellow, Pink	Sun to semi-shade	Well drained	●	●	●	●				●		●
Shrub	Blackthorn	*Bursaria spinosa*	Pittosporaceae	Sclerophyll forest, Woodland	1.5–4 m	White	Sun to semi-shade	Variable, Well drained	●	●	●	●	●	●				●
Shrub	Crimson Bottlebrush	*Callistemon citrinus*	Myrtaceae	Shrub & Woodland	1–3 m	Red	Sun to semi-shade	Moist, Well-drained	●	●	●	●		●	●			
Shrub	Common Fringe-Myrtle	*Calytrix tetragona*	Myrtaceae	Heath & Woodland, Forest	0.5–5 m	Cream, Pink	Sun to semi-shade	Well drained	●	●	●	●	●		●			●
Shrub	Gorse Bitter Pea	*Daviesia ulicifolia*	Fabaceae	Open forest	< 2.5 m	Yellow, Red	Sun to semi-shade	Well drained	●	●	●	●	●	●				●
Shrub	Sieber's Parrot-Pea	*Dillwynia sieberi*	Fabaceae	Dry Sclerophyll Forest, Woodland	0.5–2.5 m	Yellow	Semi-shade	Well drained	●	●	●	●	●	●				●
Shrub	Sticky Hopbush	*Dodonaea viscosa* subsp. *cuneata*	Sapindaceae	Mallee, Semi-arid, Open forest	< 3 m	Inconspicuous	Sun to semi-shade	Well-drained	●							●		●
Shrub	Winter Apple	*Eremophila debilis*	Scrophulariaceae	Woodland	< 1 m	Blue, Pink, Mauve	Sun	Well-drained	●	●	●	●		●				●
Shrub	Large Wedge Pea	*Gompholobium grandiflorum*	Fabaceae	Heath, Dry Sclerophyll Forest	< 1 m	Yellow	Sun to semi-shade	Well-drained	●	●	●	●		●			●	●
Shrub	Rough Guinea Flower	*Hibbertia aspera*	Dilleniaceae	Heath, Woodland, Forest	< 0.6 m	Yellow	Sun to semi-shade	Moist, Well-drained	●		●	●					●	●
Shrub	Native Indigo	*Indigofera australis*	Fabaceae	Woodland	1.5 m	Mauve	Semi-shade	Moist, Well-drained	●	●	●	●	●	●	●	●	●	●
Shrub	Jellybush	*Leptospermum polygalifolium*	Myrtaceae	Dry Sclerophyll Forest	0.5–3 m	White	Sun to semi-shade	Well-drained	●	●	●	●						
Shrub	Slender Rice Flower	*Pimelea linifolia*	Thymelaeaceae	Bushland, Open Forest	< 1.5 m	White	Semi-shade	Well-drained	●	●	●	●	●	●			●	●
Tree	Black Wattle	*Acacia decurrens*	Fabaceae	Dry Sclerophyll Forest, Woodland	3–10 m	Yellow	Sun to semi-shade	Well-drained	●		●	●	●	●	●	●	●	●
Tree	Parramatta Wattle	*Acacia parramattensis*	Fabaceae	Open forest, Woodland	2–15 m	Yellow	Sun	Well drained	●		●	●	●	●	●	●	●	●
Tree	Black She-Oak	*Allocasuarina littoralis*	Casuarinaceae	Tall Heath, Woodland	5–15 m	Red	Sun	Well drained	●		●	●	●					
Tree	Narrow-Leaved Apple	*Angophora bakeri*	Myrtaceae	Woodland	10–18 m	Cream	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree	Sydney Red Gum	*Angophora costata*	Myrtaceae	Woodland	10–30 m	Cream	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●	●	●
Tree	Spotted-Gum	*Corymbia maculata*	Myrtaceae	Woodland, Dry Sclerophyll Forest	< 45 m	Cream	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●		
Tree	Blueberry Ash	*Elaeocarpus reticulatus*	Elaeocarpaceae	Eucalypt Forest	4–10 m	White, Pink	Sun to semi-shade	Moist, Well-drained	●	●	●	●	●				●	●
Tree	Narrow-Leaved Red Ironbark	*Eucalyptus crebra*	Myrtaceae	Grassy & Sclerophyll Woodland	< 35 m	Cream	Sun to semi-shade	Well drained	●	●	●	●	●	●	●	●		
Tree	Thin-Leaved Stringybark	*Eucalyptus eugenioides*	Myrtaceae	Woodland	< 30 m	Cream	Sun	Well drained	●	●	●	●	●	●	●	●		
Tree	Grey Box	*Eucalyptus moluccana*	Myrtaceae	Grassy Woodland, Forest	< 25 m	Cream	Sun to semi-shade	Moist, Well-drained	●	●	●	●	●	●	●	●		
Tree	Mugga Ironbark	*Eucalyptus sideroxylon*	Myrtaceae	Woodland	< 35 m	White, Red	Sun	Well drained	●	●	●	●	●	●	●	●	●	●
Tree	Forest Red Gum	*Eucalyptus tereticornis*	Myrtaceae	Wet & Dry Sclerophyll Forest	< 50 m	Cream	Sun to semi-shade	Moist, Well-drained	●	●	●	●	●	●	●	●		
Tree	Cherry Ballart	*Exocarpos cupressiformis*	Santalaceae	Variable	6–9 m	Cream (inconspicuous)	Semi-shade	Well drained	●	●					●	●		
Tree	Turpentine Tree	*Syncarpia glomulifera*	Myrtaceae	Forest, Rainforest	< 45 m	Cream	Sun to semi-shade	Moist, Well-drained	●	●	●	●	●	●	●	●	●	●

Know your pollinators

European honey bee
(Apis mellifera) © iStock

European honey bees have two pairs of wings and long, segmented antennae. They are daytime-flying and feed on nectar and pollen. They are generalist pollinators and provide the bulk of pollination services for horticulture and crop plants. Honey bees and native bees are both essential to functioning ecosystems and food security in Australia.

Honey bees have become an important part of the Australian landscape. Honey bees live as colonies, and have a long history of coexistence with humans, including in domestic gardens.

Leafcutter bee
(Megachile maculariformis) © Karen Retra

Australian native bees comprise more than 2000 species, which provide essential pollination services. Native bees are generally solitary and live in nests in the ground or in hollow stems, old borer holes and other cracks and crevices, and some have evolved to pollinate particular native flowers through 'buzz pollination'. Although many Australian native bees are generalist foragers, some species have co-evolved with native plants and adapted to be the most effective pollinators of their flowers. Many native plant species, such as *Dianella* and *Grevillea* require specially adapted insects to access their nectar and enable the transfer of pollen to the stigma. Most native bees are solitary, but some species found in northern Australia (*Tetragonula* sp. and *Austroplebeia* sp.) are social bees and are used for commercial pollination of crops like macadamia nuts.

Bee fly
(Family Bombyliidae) © Karen Retra

Fly species number up to 30,000 in Australia, and can be identified by having only one pair of flight wings. A second set of wings are modified into club-shaped paddles that allow flies to hover and stabilise their flight. Unlike bees and wasps, many flies (Brachycera) have very small, clubbed antennae at the front of their head. Flies, including blowflies, are often attracted to flowers that smell like carrion. Some flower-flies, have hairy bodies that easily collect pollen while they are feeding. Flies provide a range of services in the garden, including pollination, decomposition and predation.

Hoverfly
(Family Syrphidae) © Karen Retra

Hoverflies are a type of fly, distinguishable by their large eyes, short antennae, bright black and yellow abdomen and their hovering flight behaviour. Adult hoverflies are nectar and pollen feeders. Hoverfly larvae feed on pests such as aphids, thrips and leafhoppers and are excellent biocontrol agents.

Fiddler Beetle
(Eupoecila australasiae) © Erica Siegel

Beetles have hard outer wings that form their distinctive beetle shape. Their outer wings form a T-shape where they join at the top, unlike bugs where the outer wings make an X- or Y-shape. Some beetles feed on nectar and pollen, usually by crawling over flower surfaces. There are around 30,000 species of beetles in Australia, with many yet to be formally described.

Meadow argus
(Junonia villida) © J. Hort

Butterflies have wings covered in tiny scales. They have clubbed antennae and hold their wings upright when at rest. They are day-flying and have long tongues that they can use to feed on nectar in flowers with deep tubes. Butterflies are usually brightly coloured, with approximately 600 species found in Australia.

Beautiful leaf moth
(Gastrophora henricaria) © Karen Retra

Moths also have wings covered in tiny scales and tend to be subtle in colour. They have antennae without clubs and hold their wings flat when at rest. They are generally dusk- and night-flying but there are some exceptions: the grapevine moth is a commonly seen day-flying moth. Moths feed on nectar. Australia has a high diversity of moth species, with up to 22,000 species thought to exist across the continent.

Flower forms

© Meredith Cosgrove

Generalist flowers can be pollinated by many different insects and animals. They are typically saucer shaped with many stamens and have a surface that insects can walk on. *Eucalyptus* flowers and daisy flowers are generalist flowers – they can be pollinated by bees, flies, beetles and butterflies.

© Meredith Cosgrove

Specialist flowers have modifications to their shape and size that only let certain pollinators access the nectar and pollen. These flowers might have deep flower tubes or narrow entry points so that only a select group of pollinators can access them. The advantage of specialisation is that pollination is very targeted and efficient, with accurate pollen placement made possible by co-evolution between flowers and insects. The disadvantage is that if the correct pollinator isn't there, the flowers aren't pollinated. Often, nectar is produced at the base of the flower, forcing pollinators to enter the flower fully and in the process, become covered in pollen.

Pollinator rewards

Nectar is a sugary solution, rich in carbohydrates, vitamins and minerals, produced by flowers and sometimes by glands on leaves or stems (called extra-floral nectaries). Nectar is attractive to insects, and provides an immediate energy source needed for tasks such as hunting pest insects, laying eggs in decomposing organic matter, collecting pollen, or parasitising other insects.

Carbohydrates alone don't support everything needed for health and growth, so insects also need pollen.

Pollen is rich in protein, fats and nutrients. Bees are vegetarian, and need to collect pollen to feed their offspring.

Buzz pollination

Some flowers do not produce any nectar; they specifically target pollen-collecting bees, and only offer pollen rewards. To limit pollen loss and ensure effective pollination, some plants produce flowers with specialised, tubular anthers, that only open at the tip. To extract pollen, bees use vibrations to 'buzz' the pollen grains out of the pores of these anthers. Many crops are buzz pollinated, including tomatoes, potatoes, eggplants, capsicum, chillies, tomatillo and cranberries.

European honey bees are unable to buzz pollinate flowers, but several native bees, such as the blue-banded bee, teddy bear bee (*Amegilla* sp.) and carpenter bee (*Xylocopa* sp.) are exceptionally good large buzz pollinators, and have evolved to pollinate native plants such as flax lilies (*Dianella* sp.). Many of our smaller, ground nesting bees utilise vibration to help them excavate their burrows, and they also use that skill to buzz pollen from the anthers of native plants.

Planting buzz-pollinated species will encourage populations of buzz pollinators for successful pollination of food crops and ensure seed set in native plants. Many small ground nesting bees also buzz pollinate native flowers.

Nectar feeding

Grevillea flowers and other tubular flowers are often adapted to be successfully pollinated by birds. Pollen is 'presented' on a floral stigma that extends outside the flower. When birds feed on the nectar, pollen is deposited on their beaks or heads. Bees, also attracted to the sugary nectar, crawl into the side of the flower and feed on the nectar without encountering the pollen-laden stigma. The plant doesn't receive the pollination benefit from the insect, but flowers such Grevillea species can be a very useful source of nectar for insects in the cooler months.

Nurseries

Most of the plants shown in the planting guide will be available at nurseries that have a good stock of native plants. But if your local nursery doesn't stock the plant you're after, ask them to order it in. For a list of nurseries that stock all the plants shown in the planting guide, plus other useful resources, visit the Wheen Bee Foundation website or scan the QR code.

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WheenBeeFoundation.org.au/our-work/powerful-pollinators

Wheen Bee Foundation

Powerful Pollinators Planting Guides are produced by Wheen Bee Foundation. We fund vital strategic research and education initiatives that strengthen bees, improve pollination efficiency, and protect our food security and ecosystem health. Visit the website for more information.

WheenBeeFoundation.org.au

Far left: The spreading flax lily, *Dianella revoluta,* is buzz pollinated.

Left: This European honey bee is 'side-working': feeding on the nectar-rich flowers without coming into contact with the plant's pollen.

Front cover:
1. *Exoneura* bee on native flower. (Photo: Amy-Marie Gilpin)
2. Hawkesbury Lookout, NSW. (Photo: Andrew Williamson)
3. European honey bees, *Apis mellifera.* (Photo: Kirrily Hughes)

Proudly funded by the NSW Government in association with Western Sydney University and Hort Innovation.

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THE CONVERSATION

Academic rigour, journalistic flair

Théotime Colin, Author provided

Australia is in a unique position to eliminate the bee-killing Varroa mite. Here's what happens if we don't

Published: May 24, 2023 11.51am AEST

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Varroa mites – notorious honey bee parasites – have recently reached Australian shores, detected at the Port of Newcastle in New South Wales last year. If they establish here, there would be significant implications for agricultural food security, as honey bees are heavily relied on for the pollination of many crops.

However, while Australia is the last continent to be invaded by the mite, it has an opportunity to be the first to eradicate it.

Varroa destructor is a small mite that attaches to bees and eats their "fat body". The fat bodies of honey bees are the insect equivalent of a liver. Varroa weakens bees, reduces their lifespan and increases the spread of deadly viruses.

Scientists need to be ready: this might be Australia's best chance to collect important data on the spread and evolution of this parasite. Our new paper published today in Biology Letters outlines what questions scientists need to ask and what data they need to collect if Varroa spreads in Australia.

Such data could help us understand how parasites evolve, why Varroa are so damaging for honey bees, and how Varroa mites impact other insects and the environment.

Read more: Explainer: Varroa mite, the tiny killer threatening Australia's bees

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Will Varroa establish in Australia?

Australia is in close proximity to countries that have the mite, including New Zealand, Papua New Guinea, Timor-Leste and Indonesia.

This probably explains why invasive honey bee swarms are frequently intercepted at our ports, many of these carrying Varroa. Australia currently bans importation of honey bee colonies due to the biosecurity risk, so these interceptions are typically due to stowaway swarms taking up residence in shipping containers.

Previous invasions of Varroa have been successfully eradicated before establishing, but this time Varroa circumvented the biosecurity surveillance near Newcastle and spread locally.

The New South Wales Department of Primary Industries has been contact-tracing and culling hives in contaminated areas, and the spread has been slow so far. Australia has large populations of feral honey bees, which could potentially act as a reservoir for Varroa and are much harder to trace and control, so the department is tackling this with a wild honey bee baiting program.

A Varroa mite fallen from a hive in France. Théotime Colin, Author provided

What threats does Varroa pose?

Varroa mites are a threat to food security. Although Australia has an abundance of food and exports it to other nations, the price of food is likely to increase if Varroa escapes confinement.

Currently, pollination of crops in eradication zones such as berries in Coffs Harbour is at risk due to the removal of all honey bees in the region, which may lead to short-term increases in food costs.

However, establishment and spread of Varroa will lead to lower pollination and lower crop production across the country, which will raise the price of most fruit and vegetables that depend on bee pollination.

This could worsen the food affordability crises caused by the current inflation, affecting the ability of low income households to buy nutritious and fresh produce. Almond pollination has already noted a deficit of 80,000 hives in the last season.

Many of the honey bee colonies that pollinate our crops are thought to be feral, living in tree hollows or nest-boxes designed for native animals. These feral bees are not managed by beekeepers and so won't be saved by the use of Varroa treatments, meaning they will most likely disappear.

Varroa may be a threat to wild pollinators including native bees. Varroa often spreads viruses, which can jump between species and may threaten our wild native pollinators. Of particular concern are viruses that deform insect wings and cause paralysis. Fortunately, these viruses have not been detected in the current Varroa incursion.

Australia currently relies on pollination by commercial honey bees (yellow), supplemented by feral honey bees (brown), though we have many native bee species like stingless bees and blue banded bees that are also being used in crop pollination. Boris Yagound, adapted from Chapman et al. 2023, CC BY

How can we secure Australia's agricultural industry?

Australia's agricultural industry relies mostly on pollination by European honey bees. This choice has been risky.

In Europe, pollination services are also provided by diverse species like bumble bees, mining bees and mason bees (e.g. *Osmia rufa*), many of which are un-managed wild species that nest alone.

If Varroa escapes confinement, beekeepers will still be able to maintain colonies of honey bees but at greater costs, due to colony losses and the need for chemicals to treat Varroa mites in the hives. These costs have the potential to sink businesses, and affect the livelihoods of beekeepers.

Australia needs to decrease its reliance on the European honey bee in agriculture and improve pollinator diversity via the use of other native pollinator species such as native stingless bees, blue banded bees, or even flies. For example, native Australian stingless bees aid in the pollination of macadamia and capsicum crops and could be used for the pollination of other crops.

Native blue banded bees pollinating tomatoes in Australia.

Australia's unique situation

Australia is different from other Varroa infected regions of the world. Our incursion was smaller, it was identified early and the management zone is small enough to be feasibly eradicated.

Even if Varroa spreads in Australian landscapes, hopes are that the pace of the spread may be slower in Australia than it was in other regions due to the smaller incursion, the colossal eradication effort and large tracts of land that are inhospitable to honey bees. Managed honey bee populations are concentrated around coastal regions, or in Australia's major rural food bowl regions where pollinator-dependant crops (such as almonds, blueberries and apples) are located.

This gives us a chance to prevent the spread of Varroa across inland Australia, where there are no honey bees.

Luckily for us, most of the world has already spent the last few decades trying to minimise Varroa mite management costs. As a nation, we now have the chance to initiate a fresh and coordinated management response. Australia could organise state-wide integrated pest management approaches and treatment regimes to prevent Varroa's resistance to chemical treatments from developing rapidly.

In short, there are good reasons to remain positive about the future of Australian beekeeping and horticultural industries, but there is still much work for our research community to do.

Read more: Bees can do so much more than you think – from dancing to being little art critics

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