Natural predators of vineyard insect pests

A guide to the natural enemies of grapevine pests in South Australia

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retallack viticulture
wine growing for the future

LANDSCAPE SOUTH AUSTRALIA
HILLS AND FLEURIEU

Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon, and we pay our respects to their Elders past and present. We acknowledge and respect the deep spiritual connection and the relationship that Aboriginal and Torres Strait Islander people have to Country. We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia and across Australia.

Image: Dan Bovalino

Acknowledgements

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From our Chair

The Hills and Fleurieu region contains a remarkable diversity of landscapes, soils, climatic zones and microclimates. It is also home to a number of viticultural regions widely recognised for the quality and variety of their wines – including the Adelaide Hills, McLaren Vale, Southern Fleurieu, Currency Creek and Langhorne Creek wine regions.

This new guide, 'Natural predators of vineyard insect pests', explains how the presence of certain insects and spiders can ultimately improve grape quality and quantity, and how to encourage them to thrive on your property.

Developed in consultation with entomologists and viticulturists, this guide provides practical information which growers can use straight away to understand what certain species look like, why beneficial insects are useful, what they need to thrive, and how they interact with key insect pests. This information will be useful for developing management strategies and ultimately reducing use of pesticides.

Many of the 'beneficials' that predate on crop pests are native – and so their populations are enhanced by the presence of native plants. Through re-planting programs, using locally-adapted native species growers can rapidly re-establish much needed habitat for beneficial insects and spiders. In turn, these plants help to improve the resilience and function of the landscape as a whole, through the improvement of biodiversity.

On behalf of the Hills and Fleurieu Landscape Board I commend this guide to you, and trust that it will contribute to making a difference to the practice of viticulture together with enhancing our precious environment. Remember 'good bugs equals good wine'!

David Greenhough
Chair,
Hills and Fleurieu Landscape Board

From the Grower

A guide like this one is great, it helps us know exactly what we are looking for, and how beneficial these bugs are to our vineyard management.

The goal for us is understanding the economic threshold and prevent a pest population from reaching the point where its damage causes monetary losses that are equal to the cost of control. When we avoid unnecessary spraying and allow nature to do the work, then we know things are in balance, and that's how we like it.

It's a combination approach for us, in recent years we have intentionally reduced sulphur use to favour our beneficial insect populations. In addition, we have purposely released *Cryptolaemus* (a predatory ladybird beetle) to tackle scale, as well as improved the surrounding biodiversity through large scale plantings of native shrubs and grasses as a food source.

When it comes to managing our vineyard, it's just terrific to see the amount of beneficial insects out there when you start looking. The new biodiversity plantings are already hosting numerous good bugs, from which we are now seeing them flow into the vineyard. Looking amongst the vines we regularly see lacewing and lady beetle larvae, which is just fantastic!

I just love it – when you get the microscope out, it's amazing what you see, it's like a zoo of predatory mites out there!

At Shingleback, we see how important it is to do our part. We see replanting habitat and managing the vineyard to create the right conditions for our beneficial insects as a long way towards keeping our pest population down and reducing the need for sprays.

Paul Mathews
Vineyard Manager, Shingleback Wines,
McLaren Vale

Paul Mathews, Shingleback Wines, McLaren Vale.

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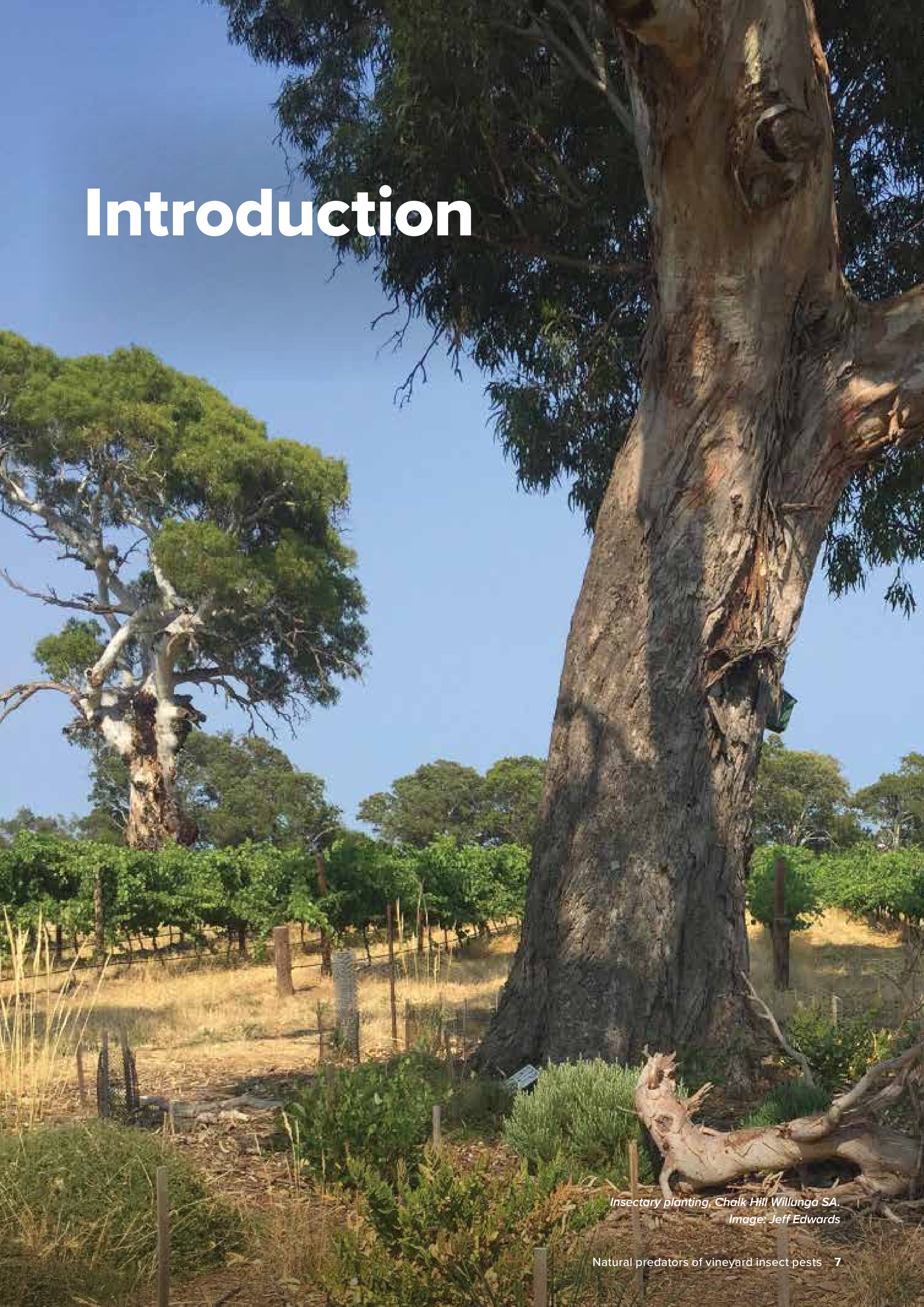


Insectary planting, Chalk Hill Willunga SA.
Image: Jeff Edwards

1. Introduction

This document provides information on the natural predators of vineyard insect pests in South Australia. These predators are known as beneficial predatory arthropods, 'beneficial arthropods', 'natural enemies' or 'beneficial bugs', and include insects, spiders and mites.

They are beneficial because they help control economically damaging pests in crops, and because of this, they are referred to as **biological control** agents (often abbreviated to 'biocontrol' agents).

By encouraging the biological control of vineyard pests, growers can reduce their reliance on chemical inputs – thereby potentially reducing costs, improving grapevine quality, and benefiting the environment.

Beneficial arthropods are primarily native species that can be attracted to agricultural properties – and sustained within them – via the introduction or enhancement of areas of locally-adapted native vegetation. This native vegetation can be situated adjacent to or within vineyards, and can include grasses, forbs, sedges, rushes, shrubs and trees.

Such plantings also improve landscape biodiversity, health and amenity – including soil health and soil biodiversity – and provide habitats for a range of other local species that can also benefit agriculture, such as insect-eating birds and microbats.

Arthropods are invertebrate animals with segmented bodies and jointed limbs. There may be up to 10 million species (Ødegaard 2000), accounting for over 80 per cent of all known living animals. The actual number of species, however, remains difficult to determine.

Athropods include insects, arachnids (spiders, mites, etc.), myriapods (millipedes, centipedes, etc.) and crustaceans. Of all ecological groups on land, insects are the most species-rich – and this is also true of freshwater environments.

Commonly encountered insect and arachnid species that provide biological control of insect pests are covered in this guide.

The guide highlights the contribution that beneficial arthropods make towards biological control of economically damaging grapevine pests. Also highlighted are some of the locally-adapted plant

species that can provide food and habitat for beneficial arthropods. A community of such plants is called an **insectary** – as it creates a sanctuary for beneficial insects.

The guide also explores the importance of functional biodiversity enhancement, which in turn supports the balanced and biodiverse viticultural ecosystems that provide a high-level of ecosystem services to the landscape.

Biodiversity is species diversity and species richness; while an **ecosystem** is a biological community of interacting organisms and their physical environment. Biodiversity covers the variety of species found in a place; and **functional biodiversity** is a component of biodiversity concerning the range of functions that species perform within an ecosystem.

The range of benefits that humans derive at no cost from well-functioning ecosystems and the natural environment are called **ecosystem services**. A well-known example of an ecosystem service is the pollination of crop plants by bees. Beneficial arthropods also provide ecosystem services by controlling pest species in crops.

The long-term trend towards monocultures in agriculture – combined with a decline in neighbouring insect-attracting forage plants – leads to inadequate year-round food resources for beneficial arthropods. This can cause a decline in insect and arachnid diversity and population, which in turn causes a decline in valuable ecosystem services.

Overuse of pesticides – especially broad-spectrum chemicals – puts additional pressure on off-target species such as beneficial arthropods.

It is hoped that growers and advisors will use this reference guide to find out more about the types of beneficial arthropods that are likely to be observed in and around South Australian vineyards – and that it will also encourage biodiversity plantings that help attract and support such 'beneficials'.

The guide is, however, only an introduction to the wonderful and complex world of beneficial arthropods – but hopefully it will encourage those who would like to find out more.

This guide also includes a **glossary** that explains a number of terms relating to arthropods and biodiversity that may be unfamiliar to the general reader.

1.1. Why biological pest control is important for viticulture

The biological control of insect pests is a key component of the arthropod-mediated ecosystem services utilised to manage pests in productive systems.

Beneficial predatory arthropods found in associations with insectary plants have the capacity to provide biological pest control in vineyards. 'Biocontrol' is not delivered by a single key predatory arthropod, but by a whole range of organisms that appear at the same time, or succeed one another, over the course of a season, each contributing to overall pest control (Bernard et al. 2006b).

> There are millions of little insect workers that have the capacity to contribute towards biocontrol of unwanted pests virtually for free – if we understand how to attract and look after them!

Insectary plants provide food, shelter and alternative prey or hosts, which nourish and support the presence of predatory arthropods. In turn, predators provide 'regulating' ecosystem services, which involve biological suppression of vineyard pests. Stands of native vegetation adjacent to vineyards enhance biodiversity and provide season-long benefits to boost the activity of beneficial predators and parasitoids.

Optimal biological control in vineyards can be achieved by minimising the use of broad-spectrum insecticides that may kill or damage beneficial predator populations. Furthermore, the overuse of pesticides may result in a range of unintended consequences, including the potential development of resistance in some arthropod pests such as mealybugs, scale insects, moths and mites.

Ideally, pest control is achieved using biological control and cultural methods, with targeted application of selective insecticides used to reduce pest populations to below damaging levels only when required.

Cultural methods of control include weed control to remove overwintering and breeding sites provided by host weeds. Biological control options may also include the use of 'soft' insecticides such as *Bacillus thuringiensis*, a bacterium that is toxic only to the larvae of butterflies and moths.

Production systems

Due to high levels of ecosystem disruption, agricultural production systems are typically difficult environments for predatory arthropods to thrive in. Intensifying crop production and creating larger monocultures with little natural habitat and diversity causes landscape simplification, which often leads to environmental instability.

Loss of species may also threaten ecosystem functioning and balance, resulting in increasing pest pressure and the need for insecticides to combat pest outbreaks.

> "When we kill off the natural enemies of a pest – we inherit their work!" Dr CB Huffaker.

It is generally observed, that as the proportion of suitable habitat in the landscape is reduced to less than 30% of original native vegetation cover, there will be a loss of biodiversity. That is, a reduction in species numbers, as well as population densities (Andren 1994; Hanski 2011).

A reduction in semi-natural habitat has also been linked with a reduction of biological pest control in cultivated land by up to 46% when compared with more complex landscapes (Rusch et al. 2016).

> Greater stability of arthropod populations is likely in vineyards where tillage and chemical inputs are minimised, and a greater diversity and complexity of insectary plants is promoted.

There is increasing evidence that as biodiversity increases, so does the stability of ecosystem functions over time. Diverse communities also tend to be more productive (Cardinale et al. 2012).

1.2. The benefits of predatory arthropods in viticulture

The photo on this page shows damage to grape skins caused by light brown apple moth (LBAM), *Epiphyas postvittana.* The moth provides infection sites and may predispose grapes to ‘bunch moulds’. Annual losses in Australia from *Botrytis* and other bunch rots, as well as LBAM, have been estimated at $52 million and $18 million respectively. An additional $0.5 million losses per year are caused by garden weevils, grape phylloxera, mealybugs, scale insects and trunk-boring insects (Scholefield, Morison 2010).

Other vineyard pests include Australian grapevine moth, elephant weevil and mites.

If LBAM can be managed below economically damaging thresholds, the combined annual losses caused by LBAM and bunch rots could be reduced by as much as $70 million per year.

Moreover, there is growing awareness of the dangers of chemical use. Chemicals may be harmful to the environment and human health if not managed appropriately. Cultural and biological control options can be used to reduce the level of intervention, as well as the volume of chemical required each year.

It may be possible to work smarter rather than harder by adopting longer-term solutions and letting nature take care of itself.

For more information about ‘The importance of biodiversity and ecosystem services in production landscapes’ see **https://winetitles.com.au/gwm/articles/october-657/the-importance-of-biodiversity-and-ecosystem-services-in-production-landscapes.**

Bunch botrytis from Light brown apple moth. Image: Kerry-Anne March

1.3. How mobile are beneficial predatory arthropods?

Movement between plants enables beneficial arthropods to find floral resources and alternative prey or hosts. It also allows them to seek refuge from adverse conditions such as the resource bottlenecks that occur when grapevines drop their leaves during winter.

> Native perennial plants provide valuable habitat for mobile predators.

Some predators are more mobile than others, and have the capacity to colonise areas more quickly. Ground beetles can move up to 200 m from boundary plantings into adjacent crops; minute pirate bugs and predatory thrips can disperse up to 35 m; while parasitoid insects can travel up to 80 m from insectary refuges.

In addition, spiderlings are well known for their capacity to passively colonise new areas via aerial dispersal techniques, including 'ballooning', which involves moving through the air on silken threads over significant distances.

Knowing the potential area of influence of beneficial arthropods assists with design and placement of insectary plantings, including plantings of native species in vineyard mid-rows and under vine. However, more research is required to determine the potential movement and likely area of impact of beneficial arthropod species.

Hump-backed katydid.
Image: Jeremy Gramp

1.4. How to encourage beneficial predatory arthropods

There are three simple steps growers can take:

- Reduce broad-spectrum pesticide use. Only use targeted applications of selective insecticides to reduce pest populations to below damaging levels, if they are required.
- Consider adopting a long term, integrated pest management (IPM) approach, which incorporates cultural and biological control. Monitor populations of predatory arthropods and augment this with the release of biological control agents if required.
- Incorporate a diverse range of suitable, locally-adapted, native insectary plants to boost the presence of predators and parasitoids in and around production systems throughout the entire year.

Integrated pest management (IPM) is a planned and systematic approach to pest control that seeks to minimise harm to the environment through the combined use of biological, cultural and (when determined necessary) targeted chemical methods of control.

For more information about 'The functional diversity of predatory arthropods in vineyards' see **https://winetitles.com.au/gwm/articles/january-660/the-functional-diversity-of-predator-arthropods-in-vineyards.**

Insectary garden.
Image: Jeff Edwards, McLaren Vale SA

1.5. The impact of agricultural chemicals on beneficial predatory arthropods

The use of chemicals will invariably result in collateral damage to non-target species. For example, predatory mites and parasitic wasps are particularly susceptible to high rates of sulphur and the commonly used fungicide 'mancozeb'. This may exacerbate the damage caused by pest species that might otherwise be controlled naturally.

Such effects have led to a greater emphasis on biological control to regulate plant pests. Higher populations of invasive vineyard pests, including the black Portuguese millipede, *Ommatoiulus moreleti*, are reported under high cumulative pesticide metric scores (Nash et al. 2010). This highlights the vigilance needed to minimise collateral damage to beneficial predatory arthropods from pesticide use in vineyards.

1.5.1. Monitoring and surveying pests to ensure spraying is only undertaken when critical thresholds have been reached

Thresholds provide a quantitative basis on which vineyard managers can decide if pest populations are below, at, or exceed a level that warrants the intervention and the expense of activities to reduce the pest density.

These interventions may be cultural, biological or chemical control options that aim to reduce the pest population below an economic threshold.

Monitoring and thresholds are an integral part of integrated pest management (IPM) programs, and their use can lead to a significant reduction in pesticides applied in vineyards.

It is important to know when to intervene and to choose a method which will not have unintended consequences, such as off target damage of predatory species that would otherwise contribute to biological control of pests. For instance, if mealybugs are observed along the veins on the backs of leaves in late-spring or early-summer, it may be appropriate to release biological agents, when other control options are limited. This could include introducing mealybug-destroyer ladybird beetle larvae, *Cryptolaemus montrouzieri*, and/or green lacewing, *Mallada signata*, as early as possible, so populations can increase in time to provide biocontrol before veraison and harvest.

Instead of spraying chemicals annually, which may exacerbate the issue by knocking out the natural enemies of insect pests, it may be possible to break the cycle, providing a longer-term and more sustainable solution.

If sufficient insectary plants are available after harvest to provide food, shelter and alternative prey for beneficial predatory arthropods, then they are more likely to complete their life cycle and persist in the production area through to the following season. This may save a grower considerable time, money and resources due to the averted crop loss.

Correct identification is essential

Correct identification of pests and beneficial predators, and an understanding of their lifecycle, is important. For example, the larvae of the mealybug-destroyer ladybird beetle mimic (by looking similar to) mealybug larvae. It is important to know how to identify each species accurately, especially where ladybird larvae have been released as a biocontrol agent.

Another example concerns the larvae of tortricids (leafrollers), including light brown apple moth (LBAM), which have no clear defining morphological features – so either molecular methods of identification are needed, or growers can rear larvae in containers to adulthood to identify the species of moth with confidence.

If moth larvae are observed in the mid-row on broad-leaf weeds, such as plantain or capeweed, not all species will migrate into the grapevine canopy and cause damage to the developing bunches of grapes. Moth species such as *Acropolitis rudisana*, the lucerne leafroller, *Merophyas divulsana*, and the cotton tipworm, *Crocidosema plebejana*, that remain in the mid-row, may become an important source of alternative prey for predators or hosts for parasitoid wasps (Retallack, Keller 2018).

For more information about 'Which species of tortricid leafroller do I have in my vineyard?' see **https://winetitles.com.au/gwm/articles/september-656/which-species-of-tortricid-leafroller-do-i-have-in-my-vineyard.**

1.5.2. Targeted spraying

Ideally, cultural and biocontrol options within an IPM strategy will be the primary methods of pest control.

If selective insecticides need to be used to reduce pest populations to below damaging levels, they should be applied in a targeted way – by only spraying impacted areas – to reduce the likelihood of collateral damage to the natural enemies of insect pests. Damaged areas should be tagged and monitored prior to intervention.

Growers are encouraged to learn about the lifecycle of their key insect pests and develop longer-term management strategies, so less intervention on an annual basis is ultimately required.

Restored native grassland, Adelaide Hills SA. Image: Jeff Edwards

1.6. Encouraging native plants

Enhanced biodiversity is often promoted as an important indicator of vineyard health, and non-crop plants may have the capacity to maintain and enhance biodiversity.

Native plants are preferred in insectary plantings (both adjacent to and within vineyards), as they are locally adapted to Australia's dry and hot climatic conditions. They also harbour few pests, have high occurrence of beneficial arthropods, and have the capacity to contribute towards biological control. Native plant species provide for the conservation and augmentation of beneficial predatory arthropods that are already in place or that can be readily recruited.

> Insectary plants need to be attractive to beneficial predator and parasitic species – but not to pests – and be easy to establish and maintain, without actively competing with grapevines.

For more information about 'The role of native insectary plants and their contribution to conservation biological control in vineyards' see **https://winetitles.com.au/gwm/articles/november-658/the-role-of-native-insectary-plants-and-their-contribution-to-conservation-biological-control-in-vineyards.**

1.6.1. Establishing insectaries

Stands of native vegetation adjacent to perennial production areas, including vineyards, have been associated with increased biodiversity benefits.

> Vineyard managers are encouraged to explore the use of locally adapted, native insectary plants in association with grapevines.

Existing vegetation structures such as windbreaks, vegetation corridors, beetle banks (special plantings that provide habitat for beneficial insects, birds and other fauna that prey on pests), together with mid-row, under-vine and headland plantings can be enhanced to provide resources for predators that contribute to pest control throughout the year.

For more information on 'Practical examples of ways to establish native insectary plants in and around vineyards' see **https://winetitles.com.au/gwm/articles/december-659/practical-examples-of-ways-to-establish-native-insectary-plants-in-and-around-vineyards.**

1.6.2. The benefits of inter-row plantings

Mid-row and under-vine plantings of perennial tussock grass species, such as wallaby grasses, *Rytidosperma* species, can be used to enhance the functional biodiversity in vineyards and provide biocontrol benefits.

For example, it is reported that the brown lacewing, *Micromus tasmaniae*, breeds on native wallaby grasses (Wood et al. 2011), which may increase the net number of predator morphospecies (species distinguished solely on their physical characteristics) by around 27% when planted in combination with woody perennial plants, such as Christmas bush, *Bursaria spinosa*, prickly tea-tree, *Leptospermum continentale*, and grapevines (Retallack 2019).

Biodiversity and the provision of ecosystem services can be improved by at least 20% in vineyards by retaining inter-row vegetation cover in preference to intensive soil tillage and herbicide use, and can also lead to greater resilience within the system (Winter et al. 2018).

Native plants attract three times more beneficial predatory arthropods than grapevines alone.

Many of the beneficial predatory arthropods that attack crop pests are native (Gagic et al. 2018), and such 'beneficials' may dominate the diversity of species present on locally-adapted native insectary plants.

By incorporating native plant assemblages in and around vineyards, it may be possible to increase the functional diversity offered by predatory arthropods by more than three times when Christmas bush or prickly tea-tree are incorporated, versus grapevines only (Retallack et al. 2019).

It is important to incorporate a diversity of native plants, and growers are encouraged to explore the use of suitable insectary plants in and around their vineyards.

The full complexity of ecosystem functionality isn't considered here, but the provision of floral resources, as well as the incorporation of wetlands and/or roosting perches, may help to support higher trophic groups such as microbats and/or predatory birds, which have the capacity to contribute either directly or indirectly towards biological control of insect pests.

Wetland restoration with native plantings at Shaw and Smith, Adelaide Hills. Image: James Hall

1.6.3. Key insect-attracting plants

The incorporation of the native insectary plants Christmas bush (Figure 1), wallaby grasses (Figure 2) and prickly tea-tree (Figure 3) have the potential to enhance biodiversity and conservation biological control efforts by providing a suitable habitat to support diverse and functional populations of beneficial predatory arthropods.

The opportunity to plant selected native insectary species could help winegrape growers save time and resources by producing fruit with lower pest incidence, while enhancing the biodiversity of their vineyards and properties.

Figure 1 Christmas bush, Bursaria spinosa*, exhibits a natural sprawling habit (left), small creamy coloured flowers that provide pollen and nectar (centre), and distinctive seed pods (right). Images: Mary J Retallack*

Figure 2 Wallaby grasses, Rytidosperma *species, seed head (left), planted as a mix of species in the vineyard mid-row (centre), and the underground biomass produced by the roots (right). Images: Mary J Retallack*

Figure 3 Prickly tea-tree, Leptospermum continentale*, during establishment (left), shrubs established as a shelterbelt (centre), and the pollen and nectar producing white flowers (right). Images: Mary J Retallack*

1.7. Notes on biodiversity and viticulture

A measure of functional diversity that is often employed refers to the variety and number of species that fulfil different functional roles, including the biological control of pests by predators.

When a diverse natural system is replaced with a monoculture, this often has a negative impact on biodiversity. A simplistic ecological network with fewer connections can lead to instability within a production system.

> Where there is fragmentation of the natural landscape, there is often an increase in pest pressure on crops and a greater reliance on chemical control options.

Fragmented landscapes can also have a negative effect on the abundance and diversity of beneficial predators and reduce their capacity to provide biological pest control.

In contrast, systems incorporating enhanced biodiversity can lead to greater natural biological control and resilience within the system, together with improved ecosystem services.

The resilience of a natural system describes its capacity to reorganise back to its initial state after local disturbance, or in response to environmental changes. If a greater diversity and species richness are present, then it is less likely that individual weeds or pest species will dominate.

The system may also be better able to recover from disruptions, including extreme weather.

By adopting optimised management practices and promoting the richness of the natural enemies of pest species that are present, growers can reduce the density of herbivorous pests, which may also lead to increased yield. Predatory invertebrates have a direct impact on pest abundance, and so can be used to assess the benefits of enhancing biodiversity.

For more information on 'The importance of biodiversity and ecosystem services in production landscapes' see **https://winetitles.com.au/gwm/articles/october-657/the-importance-of-biodiversity-and-ecosystem-services-in-production-landscapes.**

1.8. Trapping techniques

There is a range of reasons why a grower might wish to assess arthropod species within the grapevine canopy or insectary plantings. These include species identification (which beneficial or pest species are present), population density (the population levels of each identified species) and monitoring (assessing population levels over time).

Monitoring is used to determine if pest species are at critical levels, and, importantly, to determine if changed management practices are having an impact.

Several methods of trapping arthropod species – to allow for species identification – are described below. Utilisation of these techniques will also assist growers to become familiar with the key arthropod species that occur on their property.

1.8.1. Modified beat net

Arthropod samples can be collected from grapevines by firmly striking the cordon with a rubber mallet over a beat net fashioned around a card table frame, which holds a funnel and plastic collection container (see Figure 4).

Figure 4 A rubber mallet is used to strike the cordon to dislodge the arthropods (left), the net is placed below the cordon (centre), and insects are collected in a plastic container positioned below the funnel (right). Images: Mary J Retallack

Image: Jeremy Gramp

1.8.2. Modified sweep net

Arthropods found in association with native insectary shrubs can be collected by firmly shaking the foliage inside an insect sweep net, which has been modified to hold a funnel and a collection container. Collected arthropods can then be immobilised in the field if required. (See Figure 5).

Figure 5 Foliage is placed inside the modified sweep net (left), the captured arthropods fall to the bottom of the net (centre), and can then be immobilised in the field and placed in storage containers (right). Images: Mary J Retallack

Figure 6 Captured arthropods in a plastic container (left), a euthanising jar (centre), arthropod samples are sorted from plant debris and then identified (right). Images: Mary J Retallack

Captured arthropods can be viewed non-destructively by looking through the clear plastic storage containers. Alternatively, they can be transferred to a freezer or a euthanising jar, so that they can then be identified under a microscope (see Figure 6).

1.8.3. Pitfall traps

Ground-dwelling arthropods – including spiders and beetles – are often collected in pitfall traps. The traps can be fashioned from a range of materials, including a narrow vial or a wider container (see Figure 7).

Containers that fit inside a sleeve, flush with the soil surface, are often used. Ensure containers have a mesh cover to limit bycatch. A cover should be placed above each trap to exclude rainfall. Charge the traps with propylene glycol, or a saline solution, to a height of approximately 30 mm to euthanise and preserve the contents. Pitfall traps can be left in the field for up to two weeks prior to collection (see Figure 7).

Figure 7 Pitfall trap covered with a plastic raincover (left), recharging the trap with preservative (centre), and an example of a field processing kit (right). Images: Mary J Retallack

1.8.4. Other sampling techniques

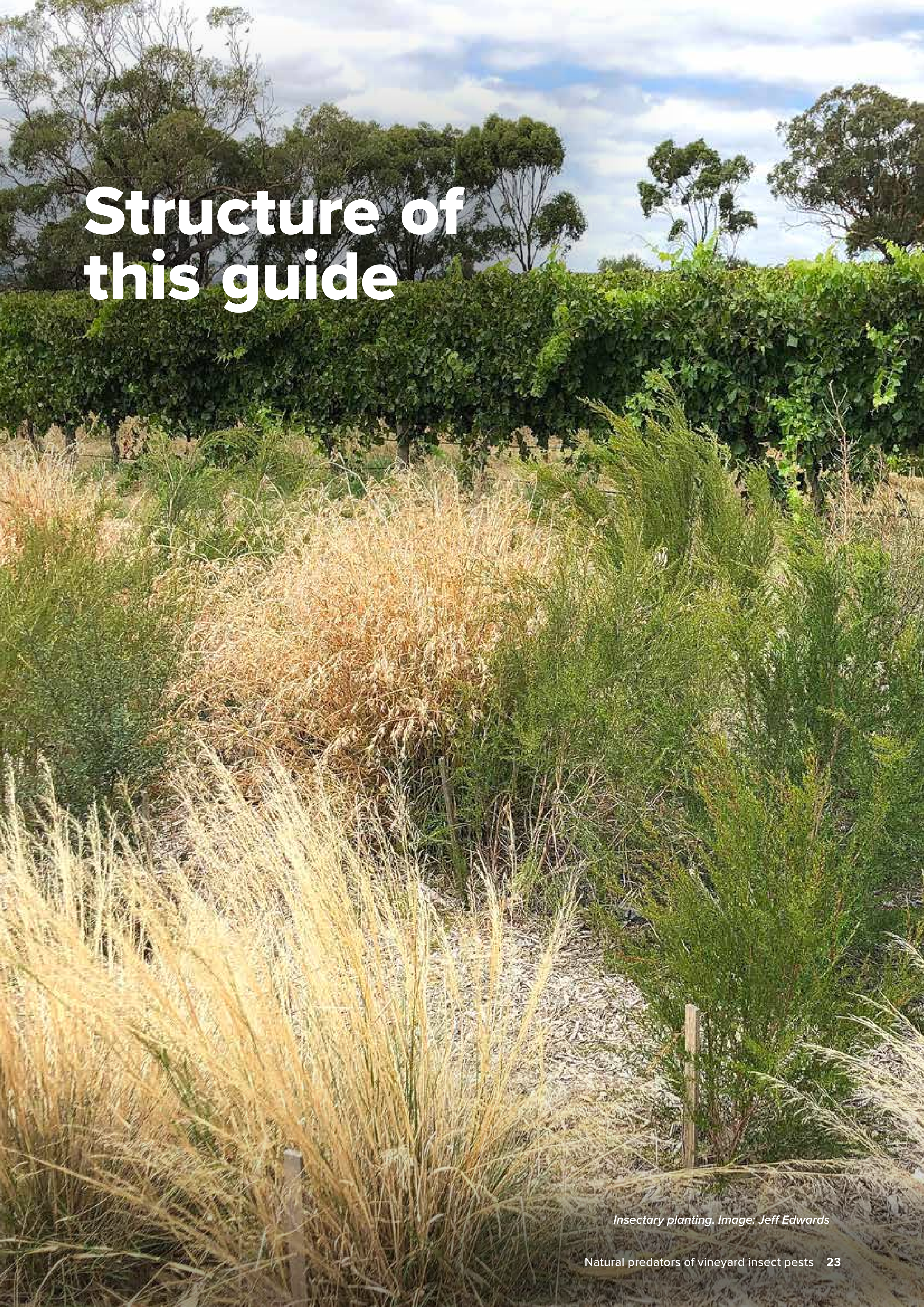
A mechanical vacuum can be used to sample vegetation by placing a tube into the air intake slot of a leaf blower, and then placing a sock over the opening of the tube. Flying insects such as moths, flies and parasitoid wasps are often sampled using yellow sticky traps placed in the canopy.

Figure 8 A mechanical vacuum is used to sample arthropods inhabiting a Goodenia plant (left), a yellow sticky trap placed below a grapevine canopy (centre), and the sticky trap stored inside a plastic sleeve to facilitate handling (right). Images: Mary J Retallack

The used sticky traps can be placed inside a clear plastic bag to facilitate the storage and identification of contents (see Figure 8).

For information on 'Ways to monitor arthropod activity on native insectary plants' see **https://winetitles.com.au/gwm/articles/february-661/ways-to-monitor-arthropod-activity-on-native-insectary-plants.**

Structure of this guide



Insectary planting. Image: Jeff Edwards

2. Structure of this guide

In this guide, some of the more interesting and commonly found beneficial predatory arthropods are presented – representing 12 Orders of insects and arachnids.

There are 30 Orders of insects (although this varies depending on the classification scheme used) – with five Orders comprising 80 percent of all insect species (the Hemiptera, Coleoptera, Diptera, Hymenoptera and Lepidoptera) – while there are 15 Orders of arachnids (again, with the number varying depending on the scheme adhered to).

The guide also includes a short section on bees – although they are not predatory arthropods – owing to local interest and their well-known importance as pollinators of a variety of plant species.

The 12 arthropod Orders represented in this guide and presented in taxonomic arrangement comprise:

1. Order Odonata I Dragonflies and damselflies
2. Order Hemiptera I True bugs
3. Order Coleoptera I Beetles and ladybird beetles
4. Order Diptera I Flies and hoverflies
5. Order Hymenoptera I Wasps, ants and bees
6. Order Neuroptera I Net-winged insects
7. Order Dermaptera I Earwigs
8. Order Mantodae I Mantises
9. Order Orthoptera I Katydids
10. Order Mesostigmata I Mites
11. Order Araneae I Spiders
12. Order Pseudoscorpiones I False scorpions.

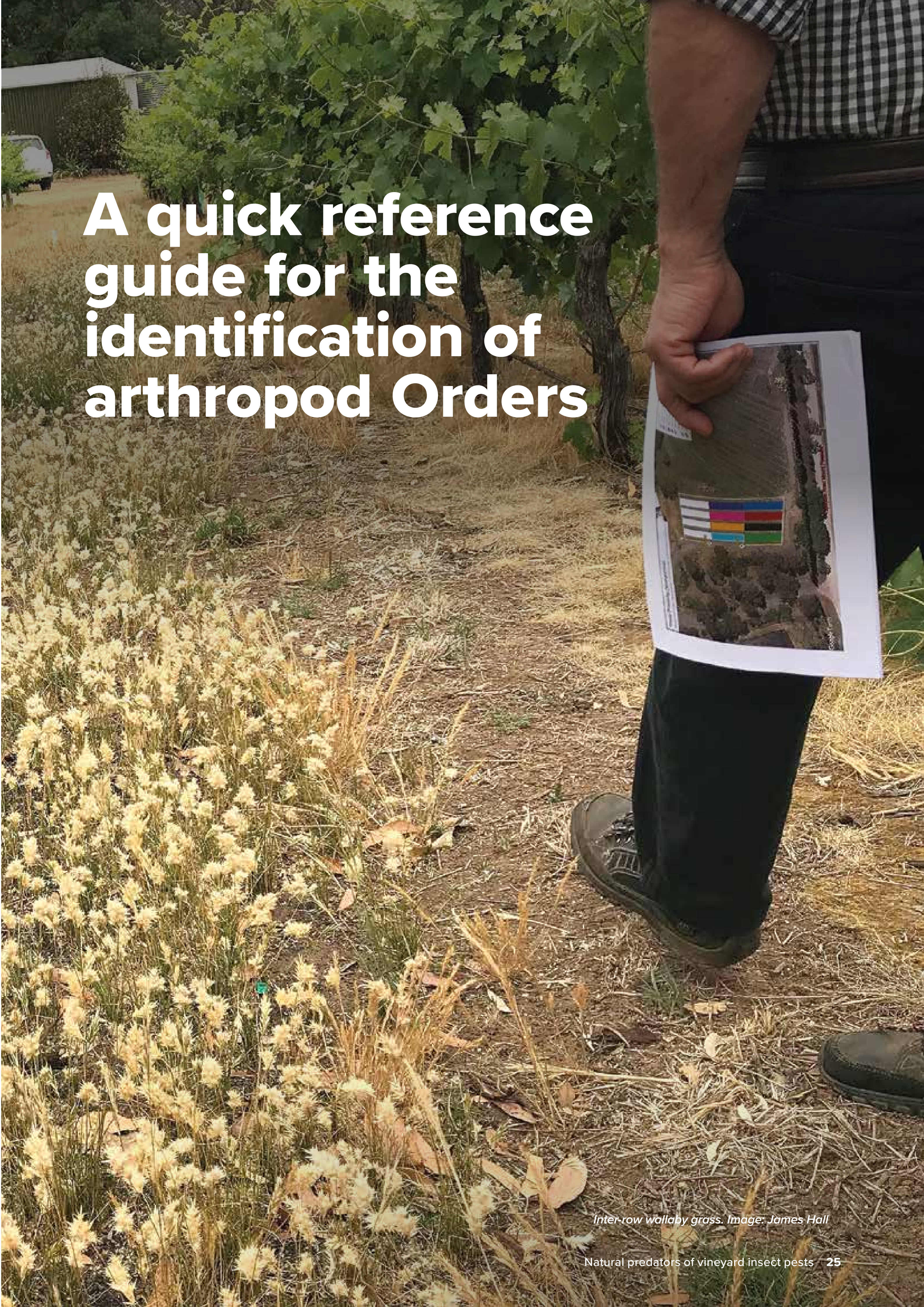
The following information is presented for each Order:

- Scientific name
- Common name
- Origin
- Distribution
- Description
- Distinctive features
- Prey
- Mode of predation
- Habitat
- Breeding cycle
- Significance to viticulture
- Sensitivity to sprays
- Amazing fact

The guide deliberately keeps the use of specialist terms to a minimum. However, the use of some specialist terminology is unavoidable – so terms that the reader may be unfamiliar with, or more familiar terms where a specific definition is required, are included in the Glossary.

> This guide is designed to serve as a practical resource to increase knowledge about the biodiverse ecosystems in which we live and work.

A quick reference guide for the identification of arthropod Orders



Inter-row wallaby grass. Image: James Hall

3. A quick reference guide for the identification of arthropod Orders

Some general tips to assist with identification of the 12 arthropod Orders represented in this guide are given below. More detailed profiles of common predators are presented in the following section.

Order Odonata

Dragonflies and damselflies: minute antennae, extremely large eyes (encompassing most of the head), two pairs of transparent membranous wings with many small veins, and a long slender abdomen.

Order Hemiptera

True bugs: adults have piercing and sucking mouthparts – while a slightly curved or straight tube (a rostrum) originates from the front of the head and rests in a groove between the legs towards the rear end of the insect.

Order Coleoptera

Beetles: round or oval body shape, hard forewings (elytra), antennae visible (varying colours, shapes and lengths), with chewing mouthparts.

Ladybird beetles: domed body shape, short legs, short, clubbed-antennae, variety of colours and patterns, with chewing mouthparts.

Order Diptera

Flies: a single pair of functional wings, with the hind wings reduced to balancing organs called halteres (club shaped and located behind the forewings), a large movable head, compound eyes that are often very large, sucking, piercing or sponge-like mouthparts (adapted for a liquid diet), and the middle segment of the thorax is enlarged.

Hoverflies: able to hover seemingly stationary in mid-air near flowers – with large round eyes covering much of the face, small antennae, predominantly yellow and black in colour, not hairy, slim legs, and a flat abdomen when viewed side on.

Order Hymenoptera

Wasps: body shape is often long and slim with a distinct 'waist'. Legs often dangle in flight, eyes oval-shaped and positioned at the side of the head, long antennae, and two pairs of long and thin wings (generally shorter than the body). The head is triangular or tear shaped, and some species have a visible ovipositor to lay eggs.

Ants: elbowed antennae, a strong narrowing of their second abdominal segment into a node-like petiole (constricted segment), mandibles for chewing, and six slender legs.

Bees: hourglass body shape with a 'waist', a cylindrical abdomen and thorax, antennae (often with an elbow), long oval eyes (often black), two pairs of wings that are shorter than the body, and a head that is triangular or tear shaped.

Order Neuroptera

Net-winged insects: adults vary in colour from bright green to brown. Transparent, lace-like wings are held tent-like over the body when at rest.

Order Dermaptera

Earwigs: elongate, with large sclerotised (hardened) abdominal forceps and mandible mouthparts.

Order Mantodae

Mantises: large predatory species with raptorial forelegs, a mobile head with large eyes, and mandible mouthparts.

Order Orthoptera

Katydids: similar in look to grasshoppers, but can be distinguished by the length of their filamentous antennae, which may exceed their own body length (grasshoppers' antennae are always relatively short and thickened).

Order Mesostigmata

Mites: tiny members of Class Arachnida with two body sections and four pairs of legs, each with six segments.

Order Araneae

Spiders: eight legs, two distinct body parts, and fangs which are able to inject venom.

Order Pseudoscorpiones

False scorpions: small arachnids, with a flat, pear-shaped body and pincers that resemble those of scorpions. The abdomen is short and rounded at the rear, rather than extending into a segmented tail and stinger like true scorpions.

Common beneficial predatory arthropods –Class Insecta

Adult damselfly. Image: Jeremy Gramp

4. Common beneficial predatory arthropods

4.1. Class Insecta

4.1.1. Order Odonata | Dragonflies and damselflies

4.1.1.1. Suborder Epiprocta | Dragonflies

Origin: native to Australia.

Distribution: found throughout Australia (Atlas of Living Australia 2019).

Description: both dragonflies and damselflies belong to the Order Odonata. They range from 20 to 150 mm in body length, and have two pairs of membranous, clear wings, which are of similar length.

Distinctive features: dragonflies can be distinguished by their eyes which are large, bulging and nearly touching. Their wings at rest, sit outstretched with all four visible. Dragonflies tend to be larger, and are generally more powerful, fast and agile fliers than damselflies.

Prey: adult dragonflies mainly eat flying insects, including mosquitoes, butterflies, moths, damselflies and smaller dragonflies. Prey is subdued by being bitten on the head. The wings are discarded and prey is typically ingested head first. A dragonfly may consume as much as a fifth of its body weight per day and they have a 95% success rate in capturing prey (Combes et al. 2012).

Mode of predation: both the adult and larval stages are predators. The legs of adults point forward, forming a basket to capture prey in mid-flight. Large dragonflies can fly up to 50 km/hr with an average cruising speed of 16 km/hr (British Dragonfly Society 2019).

Habitat: adults are territorial. They live and hunt near water sources and are also commonly found in vineyards, especially when there is a dam or creek nearby.

Figure 9 A dragonfly amongst grapes. Image: Sandra Elliot

Breeding cycle: eggs are laid into or close to water. Larvae feed on aquatic insects. They progress through up to 12 larval stages and then crawl out of the water. Finally, their skin splits down the back and the adults emerge. They inflate their wings and abdomen to gain adult form. Several years of their lives are spent as nymphs living in fresh water; whereas the adults may be on the wing for just a few days or weeks.

Significance to viticulture: adult dragonflies eat a range of flying insects, including moths.

Sensitivity to sprays: nymphs are sensitive to chemical runoff into waterways, and exposure to copper (Tollett et al. 2009). Both adults and nymphs are susceptible to broad-spectrum insecticide exposure, including pyrethroids (Mian, Mulla 1992).

Amazing fact

Dragonfly nymphs breathe through gills in their rectum, and can rapidly propel themselves by suddenly expelling water through their anus! (Mill, Pickard 1975).

4.1.1.2. Suborder Zygoptera | Damselflies

Origin: native to Australia.

Distribution: found throughout Australia (Atlas of Living Australia 2019).

Description: both dragonflies and damsel flies belong to the Order Odonata. They range in body length from 20 to 150 mm, have two pairs of wings, with both pairs membranous, clear and of similar length. Male damselflies are often more brightly coloured than females.

Distinctive features: damselflies can be distinguished via their eyes which are large, bulging and well separated. Their wings at rest sit upright, above their body, and are usually pressed flat together. Damselflies tend to be smaller in comparison to dragonflies, with slimmer bodies and a weaker fluttery flight in the air.

Prey: both adult and nymph damselflies are predatory. Adult damselflies catch and eat flies, mosquitoes and other small insects. The larvae feed on aquatic insects.

Mode of predation: they are active, diurnal predators, which capture prey in mid-flight.

Habitat: adult damselflies live near freshwater habitats such as streams and dams, and are often found in association with grapevines where there is water nearby.

Breeding cycle: when damselflies breed, the male will attach the back of his abdomen to the female's head, and in this position they fly together. They will then find a perch and mate. The female lays her eggs near or in water. Larvae progress through up to twelve larval stages and then crawl out of the water. Their skin splits down the back and the adults emerge.

They inflate their wings and abdomen to gain their adult form (Australian Museum 2019). Often damselflies live out their lives within a short distance of where they were hatched. Many damselflies are able to produce more than one brood per year.

Significance to viticulture: damselflies eat a range of small flying insects, including moths.

Sensitivity to sprays: adults and nymphs are susceptible to broad-spectrum insecticide exposure, including pyrethroids (Mian, Mulla 1992) and fipronil (Sugita et al. 2018).

Figure 10 Damselflies on grapevine. Images: Mary J Retallack

Amazing fact

The presence of damselflies on a body of water indicates that it is relatively unpolluted. In addition, more than 80 per cent of their brain is used to make sense of what they see (Australian Museum 2019).

4.1.2. Order Hemiptera | True bugs

4.1.2.1. Family Anthocoridae – Orius species | Minute pirate bugs

Origin: various, worldwide distribution.

Distribution: found in south-eastern Australia (Atlas of Living Australia 2019).

Description: adults are 2 to 5 mm in body length, and have soft, elongated, oval-shaped, flat bodies, which are often patterned in black and white. The head is extended forward, and the antennae are longer than the head.

Distinctive features: they have distinctive piercing and sucking mouthparts.

Prey: all life stages of minute pirate bugs feed on live prey, including small insects, larvae and eggs of aphids, mites, moth eggs, small caterpillars and pollen.

Mode of predation: they are fast-moving predators that are most active when temperatures are 20 to 30°C. Their mouthparts are used to inject digestive enzymes into captured prey to prepare the contents for consumption.

Habitat: found in the canopy of native vegetation, including Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*, during late spring and summer (Retallack 2019).

Breeding cycle: females live for up to two months and can lay up to 150 eggs. Once hatched the nymphs go through five developmental stages prior to maturing into adults.

Development time from egg to adult can vary from 16 to 18 days at 25°C. Females lay an average of two to three eggs per day and live for three to four weeks.

Figure 11 A minute pirate bug. Image: Jack Dykinga

Significance to viticulture: the pirate bug is used as a biological control agent of Lepidopteran (moth) eggs. They can be purchased in Australia for release into vineyards.

Sensitivity to sprays: predatory bugs are particularly sensitive to carbaryl, methomyl, fipronil, indoxacarb, organophosphates, pyrethroids and spinosad (Thomson 2012). Residues of some chemicals on foliage, or in plant tissues, may remain toxic to predatory bugs for many months (Biological Services 2019).

Amazing Fact

The scientific name is a combination of the Greek words *anthos* 'flower' and *koris* 'bug'.

Aurora bluetail damselfly. Image: Martin Stokes

4.1.2.2. Family Geocoridae – Stylogeocoris and Geocoris species | Big-eyed bugs

Origin: various, worldwide distribution.

Distribution: found throughout Australia (Atlas of Living Australia 2019).

Description: 3 to 5 mm in body length, adults are dark brown or black with prominent large eyes, and have a triangle-shaped mark on the thorax as well as folded membranous wings.

Distinctive features: prominent large, bulging eyes and a proboscis tucked under the body.

Prey: they feed on mites, thrips, aphids, insect eggs and the larvae of moths. Both nymphs and adults are predatory, and can survive on nectar when prey is scarce.

Mode of predation: big-eyed bugs have a long piercing and sucking mouthpart (proboscis), which is fine, curved and carried under the body when they are not feeding.

Habitat: commonly found in the canopy of grapevines and on surrounding native vegetation, including Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and occasionally wallaby grasses, *Rytidosperma* species. They are most active from mid-spring to early-summer (Retallack 2019).

Breeding cycle: they take approximately four weeks to develop from egg to adult depending on temperature.

Significance to viticulture: big-eyed bugs feed on insect eggs and the larvae of moths. Studies have shown that the presence of big-eyed bugs and other predators can disrupt the feeding activities of caterpillar pests, forcing them to drop from the plant to avoid immediate danger (Crawford 2015).

Sensitivity to sprays: predatory bugs are particularly sensitive to carbaryl, methomyl, fipronil, indoxacarb, organophosphates, pyrethroids and spinosad (Thomson 2012). Residues of some chemicals on foliage, or in plant tissues, may remain toxic to predatory bugs for many months (Biological Services 2019).

Figure 12 A top view (TOP) and an underside view (ABOVE) of a big-eyed bug, where the proboscis can be seen tucked under the body. Images: Mary J Retallack

Amazing fact

Big-eyed bugs can consume 25 to 50 per cent of their bodyweight in prey each day (Crawford 2015).

4.1.2.3. Family Nabidae – Nabis kinbergii | Pacific damsel bug

Origin: Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: soft-bodied, elongate, winged, terrestrial predators. Grey-brown to tan in colour, up to 12 mm in body length, with wings folded along the length of the body, which tapers towards the head. They have large, bulbous eyes and stilt like legs.

Distinctive features: many damsel bugs catch and hold prey with their strong forelegs, similar to mantids.

Prey: they are generalist predators, and will catch almost any insect smaller than themselves. They also consume nectar, and cannibalise each other when no other food is available.

Mode of predation: an 'ambush' predator. Damsel bugs have a long piercing and sucking proboscis, which is fine, curved and carried under the body when not feeding. They pursue soft-bodied prey, stabbing and extracting their body fluids once they are caught.

Habitat: commonly found in the canopy of grapevines and on surrounding native vegetation, including Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and wallaby grasses, *Rytidosperma* species. They are most active from mid-spring to late-summer (Retallack 2019).

Breeding cycle: when sufficient prey is available, the development from egg to adult takes approximately three weeks at a temperature of 28°C. Hatching nymphs are smaller versions of the adults but without wings, and they begin feeding on available food immediately. There are several generations per year (Crawford 2015).

Significance to viticulture: damsel bugs consume a wide range of soft-bodied prey, including light brown apple moth (LBAM), looper, budworm eggs and small caterpillars, leafhoppers, mirids and mites. They are considered important biological control agents as they are prolific feeders on pests.

Sensitivity to sprays: predatory bugs are particularly sensitive to carbaryl, methomyl, fipronil, indoxacarb, organophosphates, pyrethroids and spinosad (Thomson 2012). Residues on foliage, or in plant tissues, may remain toxic to predatory bugs for many months (Biological Services 2019).

Figure 13 A Pacific damsel bug, Nabis kinbergii *(top), and camouflaged against a dry grass plant stem (middle) Images: Mary J Retallack*

Figure 14 A Pacific damsel bug with its proboscis displayed (bottom). Image: Mary J Retallack

Amazing fact

Damsel bugs are most active during the night – so even though they may not be readily observed during the day, they are active and contributing towards the biological control of pests.

4.1.2.4. Family Pentatomidae – *Cermatulus nasalis* | Glossy shield bug

Origin: native to Australia and New Zealand.

Distribution: widespread, predominantly throughout southern and eastern Australia (Atlas of Living Australia 2019).

Description: females are between 10 to 12 mm in body length, and males are slightly smaller. The head is brown and has a bluntly, rounded snout. The prothorax (the first of the three segments of the thorax, which bears the first set of legs) is broadly triangular and marked with fine perforations, which are yellowish, orangey or rusty-brow in colour, with blackish markings and fine brownish-black punctuations. The underside (ventral surface) is a mottled yellowish-brown.

Distinctive features: the short, bluntly rounded snout is one of the key ways the glossy shield bug can be differentiated from exotic pest species such as the brown marmorated stink bug (BMSB), which has a longer, narrower snout and is not presently in Australia. Glossy shield bugs tend to be somewhat smaller than the BMSB. The latter also have distinctly mottled markings on their upper-side. Glossy shield bugs do not have shoulder spines, whereas another native predatory shield bug, *Oechalia schellenbergii*, has prominent shoulder spines.

Prey: they feed on a variety of soft-bodied insects.

Mode of predation: the glossy shield bug plunges its proboscis into its prey and sucks out the body fluids.

Habitat: commonly found in the canopy of grapevines and on wallaby grasses, *Rytidosperma* species, as well as on surrounding native vegetation, including Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*. They are active from late-spring to early autumn (Retallack 2019).

Breeding cycle: there is a single generation each year. Breeding takes place over several weeks during summer. The female lays an egg raft of up to 30 metallic-black eggs in neat rows on a leaf or patch of bark. The newly hatched nymphs are red with black heads, and feed initially on the bacteria that coat the eggs and on plant sap. They moult five times. Each instar (stage) looks slightly different, but all have red and black markings. Late instar nymphs are metallic blue and red.

Significance to viticulture: from the second instar onwards, they are predaceous, feeding on caterpillars (Thomson et al. 2007) and other insects with soft bodies, including beetle larvae.

Figure 15 Glossy shield bug, Cermatulus nasalis *(top), which can have a black dot on the underside of the abdomen (bottom)*
Image: Landcare Research CC BY 4.0 (top).
Image: Mary J Retallack (bottom)

Sensitivity to sprays: predatory bugs are particularly sensitive to carbaryl, methomyl, fipronil, indoxacarb, organophosphates, pyrethroids and spinosad (Thomson 2012). Residues on foliage, or in plant tissues, may remain toxic to predatory bugs for many months (Biological Services 2019).

Amazing fact

Predatory shield bugs can be found most times of the year whenever prey is present. They are also known as the 'brown soldier bug'.

4.1.2.5. Family Pentatomidae – *Oechalia schellenbergii* | Predatory shield bug

Origin: native to Australia and New Zealand.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: adults are 8 to 12 mm in body length, mottled brown or grey in colour, with pale brown legs. Part of the forewing is coloured brown, while the rest is membranous.

Distinctive features: the most striking feature of *Oechalia schellenbergii* is the pointed 'shoulders', or sharp spines, positioned on either side of the thorax, together with a triangular patch of black on the base of the abdomen where the folded wings overlap.

Prey: they feed on a variety of soft-bodied insects.

Mode of predation: the predatory shield bug plunges its proboscis into its prey and sucks out the body fluids. The mouthparts form two tubes: a narrow duct down which saliva is pumped into the prey; and a larger tube up which the partly digested food is sucked.

Habitat: commonly found in the canopy of grapevines and on surrounding native vegetation, including *Eucalyptus*, *Acacia* and *Melaleuca* species, as well as Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*. They are can be found all year round (Retallack 2019).

Breeding cycle: there is a single generation per year, and rafts of 14 to 28 eggs are laid from December to March. Each female lays several batches of eggs. Each egg has a distinctive ring of white spines on top of the black egg (see Figure 17). Nymphs go through five instars (stages), and grow into adults during summer and autumn. Adults overwinter in sheltered places.

Significance to viticulture: from the second instar onwards, they are predaceous, feeding on caterpillars (Thomson et al. 2007) and other insects with soft bodies, including beetle larvae.

Sensitivity to sprays: predatory bugs are particularly sensitive to carbaryl, methomyl, fipronil, indoxacarb, organophosphates, pyrethroids and spinosad (Thomson 2012). Residues on foliage, or in plant tissues, may remain toxic to predatory bugs for many months (Biological Services 2019).

Figure 16 A predatory shield bug, Oechalia schellenbergii*, on flowering Christmas bush (top); a raft of eggs on a grapevine leaf (middle). Images: Mary J Retallack*

Figure 17 Predatory shield bug, Oechalia schellenbergii*, eggs (bottom left); feeding on a light brown apple moth (LBAM larva (bottom right). Images: Mary J Retallack*

Amazing fact

Predatory shield bugs can be found most times of the year whenever prey is present. They are also known as the 'spined predatory shield bug'.

4.1.2.6. Family Reduviidae – *Coranus, Gminatus, Peirates and Pnirsus* species | Assassin bugs

Origin: Australia.

Distribution: throughout Australia (Atlas of Living Australia 2019).

Description: they have a narrow neck, prominent eyes, sturdy build, and a formidable curved proboscis (rostrum). The body is brown, black or orange. The wings are membranous, and are folded along the back. Adults are typically up to 25 mm in body length.

Distinctive features: assassin bugs have a large strong segmented feeding tube known as a proboscis, which is curved backwards from the head (unlike other plant sucking bugs which have a proboscis that is tacked flat under the head).

Prey: they are generalist predators that feed on a variety of soft-bodied insects, including caterpillar larvae and eggs.

Mode of predation: generally slow moving 'ambush' predators. The fore- and mid-legs are generally modified to capture or hold prey. While the prey is held and pierced, a salivary secretion is pumped into the body, which paralyses the prey and dissolves its internal tissues into a liquid that can then be consumed.

Habitat: different species are found either predominantly in the canopy or on the ground. The orange assassin bug, *Gminatus australis*, is commonly found on Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*, from late-spring to late-summer.

Brown assassin bug, *Coranus granosus*, and black ground assassin bug, *Peirates* species, are found in association with wallaby grasses, *Rytidosperma* species, and on grapevines during spring and summer. *Pnirsus cinctipes* is found on prickly tea-tree, *L. continentale*, in late-spring (Retallack 2019) and muntries, *Kunzea pomifera* (Wood et al. 2011).

Breeding cycle: nymphs are wingless, and pass through five growth stages before they become adults.

Figure 20 Orange assassin bug, Gminatus australis, *consuming a light brown apple moth (LBAM). Image: Mary J Retallack*

Figure 18 Orange assassin bug, Gminatus australis, *on Christmas bush,* Bursaria spinosa *(top and middle). Images: Mary J Retallack*

Figure 19 'Brown assassin bug', Coranus *species (bottom left); 'black ground assassin bug', Peirates species (bottom right). Images: Mary J Retallack*

Significance to viticulture: a predator of light brown apple moth (LBAM) larvae and eggs, other bugs, mirids and beetles. They are particularly effective at controlling pests when pest caterpillars are grouped together. Each will kill hundreds of pests during their lifetime (Suckling, Brockerhoff 2010).

Sensitivity to sprays: collateral damage will occur to assassin bug populations if broad-spectrum insecticides are used.

Amazing fact

The name Reduviidae is derived from the Latin *reduvia,* meaning 'hangnail' or 'remnant'. Assassin bugs have a prosternum groove in which they can insert their rostrum (proboscis) to make a sound to frighten away predators!

4.1.3. Order Coleoptera | Beetles

4.1.3.1. Family Carabidae – *Geoscaptus* and *Promocoderus* species | Ground beetles

Origin: various.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: carabid beetles have various body shapes and colourings. Many are shiny black or metallic. They have ridged wing covers (elytra), strong legs, and large mandibles and eyes. Most nocturnal species are brown or black in colour; whereas diurnal species are patterned, brightly coloured or iridescent. They range from approximately 1 to 60 mm in body length.

Distinctive features: large, strong, chewing mouth parts.

Prey: predators of aphids, caterpillars, beetle larvae, immature stages of flies, slugs, and a range of other invertebrates.

Mode of predation: both the larvae and adults are predatory. They are ground-dwelling predators that hunt for prey that fall from plants or for ground-dwelling invertebrates. Most are opportunists and feed on whatever is available, including scavenged food and plant material. Species that are active during the day hunt by sight, and have well-developed large eyes for detecting movement – using their large mandibles to capture prey.

Habitat: natural vegetation situated along the borders of crops, as well as grass strips between vine rows, provide refuges for ground beetles. They are commonly found in association with wallaby grasses, *Rytidosperma* species, and some species may also venture into the canopy of Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and grapevines. They are active throughout the year (Retallack 2019).

Breeding cycle: eggs are laid in the soil, leaf litter or rotting wood. The larvae pass through three stages before pupation. Adult ground beetles can live from one to four years.

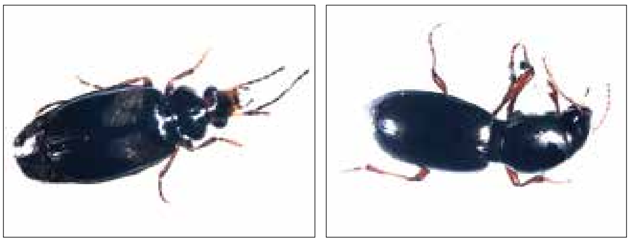


Figure 21 Ground beetle, Geoscaptus species (top). Image: Mary J Retallack

Figure 22 Ground beetles (bottom). Images: Mary J Retallack

Significance to viticulture: an important predator of ground-dwelling pests, as well as light brown apple moth (LBAM) larvae and eggs (Suckling, Brockerhoff 2010) and mealybugs (Thomson, Nash 2009).

Sensitivity to sprays: collateral damage will occur to beetle populations if broad-spectrum insecticides are used, including pyrethroids (Nash et al. 2008).

Amazing fact

Some adults hunt at night by using chemical and tactile stimuli (senses for smelling and touching). Ground beetles have glands in the lower back of the abdomen that produce noxious, or even caustic, secretions that are used to deter would-be predators.

4.1.3.2. Family Cleridae | Checkered beetles

Origin: Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: checkered beetles have elongated bodies with bristly hairs, and are usually brightly coloured (colour patterns can be red, yellow, orange or blue) with large often bulging eyes. They have strong biting mandibles and clubbed antennae at the tip; and range in body length from 3 to 25 mm.

Distinctive features: their entire bodies are covered with bristly hairs, and many display an ornate body colour pattern.

Prey: they feed on the larvae and pupae of other insects, including beetles, especially those that bore into timber.

Mode of predation: adult clerids attack other beetles, or may feed on the pollen and nectar of flowering plants. In general, adults feed mainly on other adult beetles, while the larvae feed on other beetle larvae. Some checkered beetle larvae are able to consume several times their own body weight in a day.

Habitat: found in the canopy of grapevines and surrounding native vegetation, including prickly tea-tree, *L. continentale*, Christmas bush, *B. spinosa*, and wallaby grasses, *Rytidosperma* species, during late-spring and summer (Retallack 2019).

Breeding cycle: females lay between 28 to 42 eggs at a time, predominately under the bark of trees. Larvae are predaceous and feed vigorously before pupation, and subsequently emergence as adults. The duration of the life cycle is highly variable, and is dependent on temperature and the availability of prey.

Significance to viticulture: they feed on a range of beetles and larvae. Because checkered beetles are predaceous in nature with an insatiable appetite, they are often key players in the biological control of other insects.

Sensitivity to sprays: collateral damage will occur to beetle populations if broad-spectrum insecticides are used.

Figure 23 Checkered (clerid) beetles (top and middle). Images: Mary J Retallack

Figure 24 Checkered (clerid) beetles (bottom). Images: Mary J Retallack

Amazing fact

Some species are mimics of certain ants and wasps.

4.1.3.3. Family Coccinellidae – *Coccinella transversalis* | Transverse ladybird beetle

Origin: various, wide distribution from India and south-eastern Asia to Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: adults are 4 to 6 mm in body length, and 3 to 5 mm wide, with little variation in appearance.

Distinctive features: a black head with predominantly bright red or orange elytra (hardened wing covers), and a boldly marked body with a black band down the midline and two lateral three-lobed markings.

Prey: adults and larvae consume soft-bodied insects, including both eggs and larvae. They will also consume nectar and pollen to sustain themselves when prey is in short supply.

Mode of predation: an 'active' predator. The larvae and adults have mandibles that allow them to bite and chew prey.

Habitat: readily found in the canopy of grapevines and surrounding native vegetation, including prickly tea-tree, *L. continentale*. Also found in lower abundance on Christmas bush, *B. spinosa*, and wallaby grasses, *Rytidosperma* species, predominantly during spring and summer (Retallack 2019). They are also found in association with creeping saltbush, *Atriplex semibaccata* (Wood et al. 2011).

Breeding cycle: eggs usually hatch within 2 to 18 days; while the pupal period is 7 to 14 days. Development from egg to adult usually takes 30 to 40 days. Adults can live for a few months or longer.

Significance to viticulture: the transverse ladybird beetle plays an important role in viticulture, as it preys on a wide array of plant-eating insects that damage grapevines – particularly early in the growing season – including light brown apple moth (LBAM) caterpillars and eggs (Suckling, Brockerhoff 2010), mealybugs and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage will occur to ladybird beetle populations if broad-spectrum insecticides are used. Ladybird beetles are particularly sensitive to high rates of sulphur (≥400 g/100 litres), carbaryl, methomyl, indoxacarb, organophosphates and pyrethroids (Thomson 2012). Growth regulators, such as buprofezin, are also toxic (Thomson et al. 2007). Residues on foliage may remain toxic to ladybird beetles for many weeks and negatively impact on their survival (Biological Services 2019).

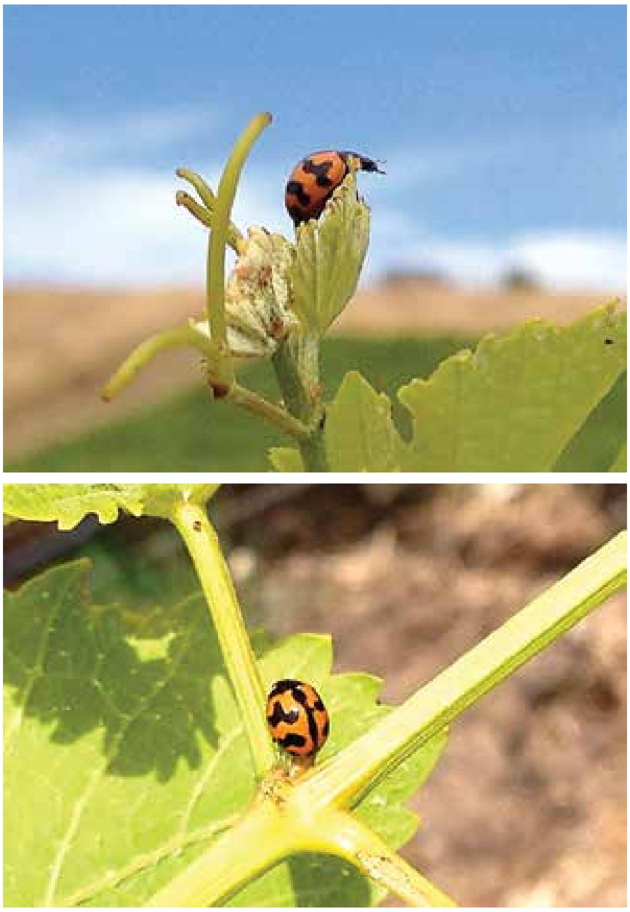


Figure 25 Transverse ladybird beetles, Coccinella transversalis, *on grapevine (top and middle). Images: Mary J Retallack*

Figure 26 Transverse ladybird beetle, C. transversalis, *on wallaby grass (bottom left); ladybird beetle larva (bottom right) Images: Jeff Edwards (left), Mary J Retallack (right)*

Amazing fact

Cannibalism occurs in coccinellids. Older larvae or adults may feed on some of the immature stages within the same or different species.

4.1.3.4. Family Coccinellidae – *Cryptolaemus montrouzieri* | Mealybug-destroyer ladybird beetle

Origin: native to Queensland and New South Wales, with broader distribution throughout the world.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: the adult beetle is about 4 mm in body length, with an orange head and black wing covers. Larvae are grey on the underside, with six black legs, and white waxy filaments on the dorsal side of the body. Larvae can reach a length of 14 to 15 mm, and closely resemble the size and shape of mealybugs.

Distinctive features: a tiny ladybird beetle with a distinctive head and black elytra (hardened wing covers), but with no spots present.

Prey: adults and larvae consume soft-bodied insects, and will also consume nectar and pollen to sustain themselves when prey is limited.

Mode of predation: an 'active' predator. The larvae and adults have mandibles that allow them to bite and chew prey.

Coccinellids that feed on scale insects lay their yellow eggs either near scale insects, underneath the scale, or on top of the scale. The larvae have mandibles that allow them to bite and chew prey. Larvae feed on mealybug eggs and young crawlers, as well as on honeydew.

Habitat: found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, predominantly during spring and summer (Retallack 2019).

Breeding cycle: adult females lay up to ten eggs per day directly into mealybug egg masses. They can lay up to 500 eggs in total. Adult beetles and young larvae feed on mealybug eggs and young stages. Large *Cryptolaemus* larvae can also consume adult mealybugs. Mealybug destroyers become adults in 24 days, after three larval stages, as well as a pupal stage. Adults can live for a few months.

Significance to viticulture: *Cryptolaemus* are a very efficient natural enemy of light brown apple moth (LBAM) caterpillars and eggs, mealybugs, and scale insects (Bernard et al. 2007; Thomson et al. 2007).

Figure 27 Cryptolaemus montrouzieri*, mealybug-destroyer ladybird beetles (top). Images: H Casselmann CC BY-SA 3.0 (left) and CC BY-SA 4.0 (right)]*

Figure 28 A fully grown larva of Cryptolaemus montrouzieri *(bottom, top of image) beside a mealybug (bottom, bottom of image). Image: Plant and Food Research NZ*

Sensitivity to sprays: collateral damage will occur to ladybird beetle populations if broad-spectrum insecticides are used. Ladybird beetles are particularly sensitive to high rates of sulphur (≥400 g/100 litres), carbaryl, methomyl, indoxacarb, organophosphates and pyrethroids (Thomson 2012).

Growth regulators such buprofezin are also toxic (Thomson et al. 2007). Residues on foliage may remain toxic for many weeks and negatively impact on ladybird beetle survival (Biological Services 2019).

Amazing fact

Cryptolaemus montrouzieri is reared for release as an important biological control agent to combat mealybugs and soft scale insects. Interestingly, its larvae resemble those of the mealybug it is designed to demolish. A case of aggressive mimicry!

4.1.3.5. Family Coccinellidae – *Diomus notescens* | Minute two-spotted ladybird beetle

Origin: Australia.

Distribution: widespread throughout south-western and south-eastern Australia (Atlas of Living Australia 2019).

Description: approximately 3 mm in body length. The body is dark greenish-black in colour, with a reddish-brown spot on each of the forewings. Minute two-spotted beetles are round and highly convex in shape, and are usually covered in fine hairs.

Distinctive features: a tiny dark greenish black ladybird beetle with a distinctive reddish-brown spot on each forewing.

Prey: aphids, eggs and immature stages of soft-bodied insects.

Mode of predation: the larvae and adults have mandibles that allow them to bite and chew prey.

Habitat: found in the canopy of grapevines and surrounding native vegetation, including prickly tea-tree, *L. continentale*, during spring and summer (Retallack 2019). They are also found on creeping saltbush, *Atriplex semibaccata* (Wood et al. 2011).

Breeding cycle: eggs are generally yellow, spindle-shaped, and laid standing on end in groups. Newly hatched juveniles complete development in 21 days at 25°C.

Significance to viticulture: a common predator of light brown apple moth (LBAM) caterpillars and eggs (MacLellan 1973), mealybugs and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage will occur to populations if broad-spectrum insecticides are used. Ladybird beetles are particularly sensitive to high rates of sulphur (≥400 g/100 litres), carbaryl, methomyl, indoxacarb, organophosphates and pyrethroids (Thomson 2012).

Growth regulators such buprofezin are also toxic (Thomson et al. 2007). Residues of some chemicals on foliage may remain toxic for many weeks and negatively impact on ladybird beetle survival (Biological Services 2019).

Figure 29 Minute two-spotted ladybird beetle, Diomus notescens *(top). Image: Mary J Retallack*

Figure 30 Minute two-spotted ladybird beetle, D. notescens *(bottom left); size comparison of ladybird beetles (bottom right) – from left to right: transverse ladybird beetle,* C. transversalis, *spotted amber ladybird beetle,* H. variegata, *and minute two-spotted ladybird beetle. Images: Mary J Retallack*

Amazing fact

Even though they are tiny, these species are abundant in the canopies of grapevines and contribute to the control of light brown apple moth (LBAM).

4.1.3.6. Family Coccinellidae – *Harmonia conformis* | Common spotted ladybird beetle

Origin: Australia.

Distribution: widespread throughout south-eastern Australia (Atlas of Living Australia 2019).

Description: orange/light reddish appearance with black spots, body broadly oval, dome-shaped and hairless. Approximately 6 to 7 mm in body length.

Distinctive features: 20 large spots – 18 of which are found on the elytra (hardened wing covers).

Prey: a wide range of soft-bodied insects, including aphids, psyllids, mealybugs, eggs of other beetles and eggs and larvae of moths (including light brown apple moth) are mostly consumed by the larvae. Adults will also consume nectar and pollen, and so are less dependent on soft-bodied prey.

Mode of predation: an 'active' predator. The larvae and adults have mandibles that allow them to bite and chew prey.

Habitat: readily found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*, all year round, but predominantly during spring and summer (Retallack 2019). They are also found on fragrant saltbush, *Rhagodia parabolica* (Wood et al. 2011).

Breeding cycle: females lay spindle-shaped, yellow eggs in clusters near prey. Larvae will emerge several weeks after eggs are laid. The entire life cycle can be as short as three weeks, depending on local climate. There are several generations per year. Ladybirds overwinter as adults.

Significance to viticulture: the common spotted ladybird plays an important role in viticulture, as it preys on a wide array of plant-eating insects which damage grapevines, particularly early in the growing season, including light brown apple moth (LBAM) caterpillars and eggs, mealybugs and scale insects (Thomson et al. 2007). *Harmonia conformis* is reared for release commercially, as an important biological control agent to combat soft-bodied pest insects.

Sensitivity to sprays: collateral damage will occur to ladybird beetle populations if broad-spectrum insecticides are used. Ladybird beetles are particularly sensitive to high rates of sulphur (≥400 g/100 litres), carbaryl, methomyl, indoxacarb, organophosphates and pyrethroids (Thomson 2012). Growth regulators such buprofezin are also toxic (Thomson et al. 2007). Residues of some chemicals on foliage may remain toxic for many weeks and negatively impact on ladybird beetle survival (Biological Services 2019).

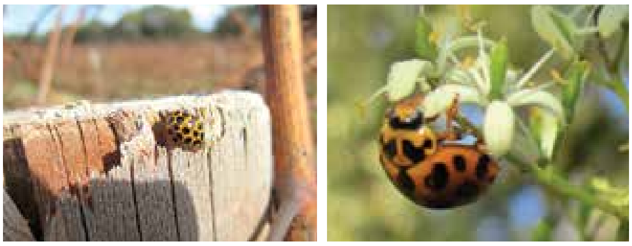


Figure 31 Common spotted ladybird beetle, Harmonia conformis, *and shown consuming aphids (top). Image: Mary J Retallack*

Figure 32 Common spotted ladybird beetle, Harmonia conformis, *in a vineyard during winter (middle left), and shown on Christmas bush (middle right). Images: Mary J Retallack*

Figure 33 Releasing reared common spotted ladybird beetle (bottom). Image: Mary J Retallack

Amazing fact

The common spotted ladybird has 20 large spots, distinguishing it from herbivorous pest ladybirds (*Epilachna* species), which commonly have 26 or 28 spots.

4.1.3.7. Family Coccinellidae – *Hippodamia variegata* | Spotted amber ladybird beetle

Origin: various, wide distribution from Europe and Asia to Australia. First observed in Queensland in 2000 (Franzmann 2002).

Distribution: widespread throughout south-western and south-eastern Australia (Atlas of Living Australia 2019).

Description: approximately 3 to 6 mm in body length, with a slightly convex and elongated body. The head is black, with dark eyes and white spots. The pronotum (the shield between the head and the wing cases) is black, with a white-yellowish border and a central black mask-shaped marking.

Elytra (hardened wing covers) are red or orange, with a variable number of black points (from none up to thirteen).

Distinctive features: the plate-like structure behind the head is black, with a white-yellowish collar. The underside of the body is black. Spotted amber ladybird beetles – also known as the 'white-collared ladybird' – are generally smaller than the transverse ladybird beetle.

Prey: adults and larvae consume soft-bodied insects, including aphids, psyllids, leafhoppers, thrips, mites and both the eggs and larvae of moths. Adults will also consume nectar and pollen to sustain themselves when prey is in short supply.

Mode of predation: an 'active' predator. The larvae and adults have mandibles that allow them to bite and chew prey.

Habitat: found in the canopy of horticultural crops and shrubs all year round, but predominantly during spring and summer (Atlas of Living Australia 2019).

Breeding cycle: eggs usually hatch within 2 to 18 days; while the pupal period is 7 to 14 days. Development from egg to adult usually takes 30 to 40 days. Adults can live for a few months or longer.

Significance to viticulture: spotted amber ladybird beetles prey on a wide array of plant-eating insects (which damage grapevines), particularly early in the growing season. They are a predator of light brown apple moth (LBAM) caterpillars and eggs, mealybugs and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage will occur to ladybird beetle populations if broad-spectrum insecticides are used. Ladybird beetles are particularly sensitive to high rates of sulphur (≥400 g/100 litres), carbaryl, methomyl, indoxacarb, organophosphates and pyrethroids (Thomson 2012).

Figure 34 Spotted amber ladybird beetle, Hippodamia variegata*, on pistachio (top and bottom).*
Images: Mary J Retallack

Growth regulators such buprofezin are also toxic (Thomson et al. 2007). Residues of some chemicals on foliage may remain toxic for many weeks and negatively impact on ladybrid survival (Biological Services, 2019).

Amazing fact

Also known as the 'adonis ladybird' or the 'variegated ladybug'. This ladybird beetle has been introduced in a range of countries as a biological control agent of soft-bodied insect pests.

4.1.3.8. Family Melyridae – *Dicranolaius bellulus* | Red and blue beetle

Origin: Australia.

Distribution: widespread throughout south-eastern Australia (Atlas of Living Australia 2019).

Description: approximately 5 to 8 mm in body length. Bright red in colour with four metallic blue spots on the elytra (hardened wing covers). Eggs are bright yellow, and larvae are orange.

Male beetles have one segment of their antennae that is greatly enlarged (Crawford 2015). When they are disturbed they tend to walk away rather than fly.

Distinctive features: a red beetle with metallic blue spots that run across both elytra (hardened wing covers) in two distinctive bands.

Prey: the eggs and larvae of soft-bodied insects, including aphids and moths, as well as other slow-moving insects.

Mode of predation: an 'active' predator. The larvae and adults have mandibles that allow them to bite and chew prey. Larvae are scavengers and predators, but the adults are the most effective predators.

Habitat: found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*, predominantly during spring and summer (Retallack 2019). The beetle manages hot and dry conditions well. Adults seek shelter in cracked soil and plant foliage for protection.

Breeding cycle: the egg, larval and pupal stages occur in the soil. Eggs are often laid in clusters on soil debris. Adult beetles may live for a year or more if there is sufficient food available. Their life cycle generally takes about one year – which means any detrimental chemical use effect on the beetle will have long lasting effects on their population.

Significance to viticulture: a predator of moth eggs and larvae.

Sensitivity to sprays: red and blue beetles are sensitive to chlorantraniliprole, spinosad and organophosphates (CRDC 2019).

Figure 35 Female red and blue beetle, Dicranolaius bellulus *(top). Image: Caroline Harding, PaDIL (CC BY-NC 4.0)*

Figure 36 Female red and blue beetle, Dicranolaius bellulus *(middle). Image: Nick Porch, Deakin University*

Figure 37 Female (bottom left) and larval (bottom right) red and blue beetles, Dicranolaius bellulus. *Images: Mary J Retallack*

Amazing fact

Beetles from the Family Melyridae are frequently referred to as 'pollen beetles', as they are often associated with and consume pollen from pollen-rich flower species. Pollen is a major food source for *Dicranolaius bellulus*, but the species is also regarded as an important predator and biological control agent in pest management programs.

4.1.3.9. Family Staphylinidae | Rove beetles

Origin: various, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: primarily distinguished by their short elytra (wing covers), that typically leave more than half of their abdomens exposed. Considerable variation exists among the species. Approximately 10 mm in body length, and often brown to black in colour. The large well-developed and protruding eyes on the sides of the head provide a clear and wide view. The adults of many species are mostly nocturnal.

Distinctive features: rove beetles are recognised by their short wing cases, which allow them to curl their abdomen up in order to project poisons from their rear end! The adult curves their abdomen upwards, like a scorpion, when running or disturbed – but they do not possess a sting. They superficially resemble earwigs, but do not have pincers.

Prey: they are generalist predators of a wide range of small insects, as well as other arthropods and their eggs. Prey are caught in the mandibles and then consumed.

Mode of predation: both the adult and larval stages are predatory. Those that live on the ground have good eyesight, which they use to pursue and capture moving prey with precision. Rove beetles that live in dense vegetation stalk their prey cautiously. They run quickly to capture prey; and can also fly.

Habitat: found predominantly on the ground in association with wallaby grasses, *Rytidosperma* species, and also in the canopy of grapevines, mostly during spring (Retallack 2019). They are also found on small-leaved bluebush, *Maireana brevifolia* (Wood et al. 2011).

Most rove beetles live their lives hidden in leaf litter or under bark. The shortened elytra and freely moveable abdomen are adaptations for foraging efficiently in dense vegetation.

Figure 38 Rove beetles. Images: Mary J Retallack

Breeding cycle: eggs are usually white and circular, or else pear shaped. Adult females can live up to 21 days and lay an average of eight eggs per day. Many species have two to three generations per year.

Significance to viticulture: a predator of a range of arthropods, including light brown apple moth (LBAM) caterpillars and eggs (Suckling, Brockerhoff 2010) and mealybugs (Thomson, Nash 2009).

Sensitivity to sprays: rove beetles are particularly sensitive to methomyl (Sharley et al. 2008), mancozeb (Thomson et al. 2007) and other broad-spectrum insecticides, especially pyrethroids, organophosphates and neonicotinoids. Residues on foliage may remain toxic for many weeks and negatively impact on their survival (Biological Services 2019).

Amazing fact

Coriaria is used for biological control and is commercially available. The species, *Paederus australis,* contains a toxin, and if the beetle is rubbed against the skin it can cause painful and itchy irritations that may lead to pustules and blistering!

Native grasses insectary planting. Image: Jeff Edwards

4.1.4. Order Diptera | Flies

4.1.4.1. Family Syrphidae | Hoverflies

Origin: various, common throughout the world, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: adults are approximately 10 mm in body length, and have black and yellow bands on their abdomen. Larvae are approximately 12 mm in length, legless and maggot shaped. Hoverflies vary in colour and patterning, but most have pale stripes down their back. They can be distinguished from caterpillars by their tapered head, lack of legs, and their opaque skin (Crawford 2015).

Distinctive features: adult hoverflies are often seen flying around like mini-helicopters, and this is how they get their common name (see Figures 40 and 82). They are fast flyers, moving in alternating bursts, and are often seen hovering in one spot near flowers. They have distinctive yellow spots on their black abdomen.

Prey: the larvae are generalist insectivores, feeding on a wide range of soft-bodied insects, including mealybugs and moth larvae and their eggs. Adults predominantly feed on nectar and pollen.

Mode of predation: hoverfly larvae are blind, so they grope around for prey. Once they have detected prey, they seize it and suck it dry.

Habitat: adults are attracted to nectar and pollen producing plants, including Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and grapevines. They are also found in association with wallaby grasses, *Rytidosperma* species, during spring and summer (Retallack 2019).

Figure 41 Local native plants like sticky boobialla, Myoporum petiolatum (syn. viscosum)*, attract hoverflies, as seen here near a McLaren Vale vineyard – often seen hovering in mid-air, darting a short distance, and then hovering again, these beneficial insects are valuable tools in the fight against aphids, thrips, scale insects and caterpillars. Image: J. Edwards*

Figure 39 Hoverfly adult (top left) and larva (top right). Images: Mary J Retallack (left), Plant and Food Research NZ (right)

Figure 40 A hoverfly, hovering in mid-flight (middle), and hoverflies mating (bottom). Images: Mary J Retallack

Breeding cycle: females lay white, oval-shaped eggs near prey, so the larvae don't have to go far to find food when they hatch after a few days. They remain larvae for about two weeks, and then pupate prior to emerging as adults. Development from egg to adult takes two to six weeks.

Significance to viticulture: an important predator of soft-bodied insect pests, including mealybugs and moth larvae and their eggs.

Sensitivity to sprays: Syrphid populations can be sensitive to some chemicals, but their high mobility in vineyards may account for the lack of detectable effects on this group (Thomson, Hoffmann 2006). Collateral damage will occur if broad-spectrum insecticides are used.

Amazing fact

Also known as 'syrphid flies', their colourful yellow and black markings mimic more dangerous wasps and bees to ward off predators.

4.1.4.2. Family Asilidae | Robber flies

Origin: various, common throughout the world, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: small to large flies that are usually grey, brown or black. They have a distinct neck, prominent and well-separated eyes, and a 'beard' of hair around the large pointed proboscis. The thorax and legs are covered in bristles or hair. Approximately 10 to 15 mm in body length.

Distinctive features: they are powerfully built, bristly flies with a short, stout proboscis enclosing the sharp, sucking mouth parts.

Prey: the name robber fly reflects their notoriously aggressive predatory habits.

Mode of predation: they feed on other insects, and often wait in ambush to catch their prey mid-flight. Each leg of the robber fly has a pair of strong claws to catch prey. They then inject a powerful poison. Enzymes help to digest the meal, and all that remains after it has been consumed is a discarded exoskeleton (Australian Museum 2019).

Both the juvenile and the adult stage feed on small arthropods. The larvae feed on other soft-bodied insects or insect eggs. Adults are most active during the hottest hours in open, sunny spaces; while at night they take refuge in dense vegetation.

Habitat: robber flies generally occur in habitats that are open, sunny, and dry. They are found in a wide range of vegetation types, including grapevines and prickly tea-tree, *L. continentale*, during spring and summer (Retallack 2019).

Breeding cycle: adults lay eggs in masses – which are usually covered in a chalky protective coating – onto plants, in gaps in soil, or into bark or wood. Larvae pupate in the soil during winter and emerge as adults in spring. The life cycle takes place over one to three years.

Significance to viticulture: they attack a wide range of prey, including beetles, butterflies and moths, ants and grasshoppers.

Sensitivity to sprays: the high mobility of robber flies in vineyards means that this information is not readily available. Collateral damage will occur if broad-spectrum insecticides are used.

Figure 42 Robber flies on grapevine (Top and Middle).

Figure 43 Robber flies on grapevine (Bottom).
Images: Mary J Retallack

Amazing fact

Also known as 'assassin flies', robber flies have sharp spines on their powerful legs, which help them to grip prey mid-flight.

4.1.4.3. Family Tachinidae | Tachinid flies

Origin: various, common throughout the world, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: some adult flies may be brilliantly coloured, while others resemble house-flies – although tachinid flies are larger and more robust than house flies; and are commonly strongly bristled. Approximately 5 to 10 mm in body length, with a wingspan of 35 mm.

Distinctive features: stout flies covered in bristles.

Prey: adult flies feed on flowers and nectar, as well as aphids and scale insects. The larvae are parasitic and feed from inside their host.

Mode of parasitism: parasitoids – adult female tachinid flies lay their eggs on or in other insects, from beetles to grasshoppers. The eggs quickly hatch, and the fly larvae feed and develop inside their host, weakening or killing it. Tachinid flies are important parasites of numerous caterpillars and other leaf-eating insects. They supplement their diet with flower nectar and insect honeydew.

Habitat: various – wherever they can find a host, including caterpillar and beetle larvae (the host being species specific).

Breeding cycle: some tachinid flies lay their eggs directly on their hosts, which then hatch and penetrate their victims. Others lay their eggs on the host's food plants, which are then consumed along with the plant. Once inside, the eggs hatch within their host, and the larvae penetrate the gut wall. The larvae have three moults before they pupate.

Figure 44 Tachinid fly on grapevine. Image: Mary J Retallack

Significance to viticulture: the tachinid fly, *Voriela uniseta*, is a larval parasitoid of light brown apple moth (LBAM) (Buchanan, Amos 1992). Tachinid flies are also predators of a range of caterpillars, beetles and bugs (Crawford 2015), including budworm, loopers, armyworms, locusts and grasshoppers.

Sensitivity to sprays: the high mobility of tachinid flies in vineyards means that this information is not readily available. Collateral damage will occur if broad-spectrum insecticides are used.

Amazing fact

Some species of tachinid flies are used in biological pest control.

4.1.5. Order Hymenoptera | Wasps

Origin: various, common throughout the world, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

4.1.5.1. Predatory Wasps

4.1.5.1.1. Superfamily Apoidea, Family Sphecidae | Thread-waisted or mud-dauber wasps

Description: thread-waisted or mud-dauber wasps are predominantly predatory.

Prey: various, including spiders, as well as various cockroaches, mantises, grass hoppers and larvae of either moths or other Hymenoptera (wasps, bees or ants).

Mode of predation: wasps capture prey, which they paralyse with a sting. The venom from the sting does not kill the prey, but paralyses and preserves it, so it can be transported and stored in the nest cell until it is consumed.

Habitat: thread-waisted or mud-dauber wasps are found in association with wallaby grasses, *Rytidosperma* species.

Breeding cycle: many nest in pre-existing cavities, or dig simple burrows in the soil, but some species construct free-standing nests of mud. Paralysed prey is placed in a closed cell along with an egg. Hatched larvae feed on the enclosed prey until fully developed.

4.1.5.2. Parasitoid Wasps

4.1.5.2.1. Parasitoid wasps – General information

Mode of parasitism: parasitoid wasps lay their eggs on or in the bodies of other arthropods, subsequently resulting in the death of the host. Different species specialise in hosts from different insect Orders, including moths, some select beetles, flies or bugs.

Habitat: chalcid wasps are found in association with grapevines, Christmas bush and prickly-tea tree. Ichneumonid wasps are found in association with grapevines, Christmas bush, prickly-tea tree and wallaby grasses. Proctotrupoid wasps are found in association with Christmas bush and prickly-tea tree.

Tiphiid wasps are found in association with grapevines, Christmas bush and prickly-tea tree. Vespoid wasps are found in association with Christmas bush, prickly-tea tree and wallaby grasses. (Retallack 2019). Braconids are found in association with windmill grass, *Chloris truncata*, and kangaroo grass, *Themeda triandra* (Wood et al. 2011).

Breeding cycle: parasitoid wasps use the egg and larval stages of other insects as hosts for their young. On finding a suitable host, eggs are laid on or in the victim, providing the wasp larvae with a meal when they hatch (Australian Museum 2019).

Significance to viticulture: there are at least 25 species of parasitic wasp that target light brown apple moth (LBAM) in Australia (Paull 2007). The most common parasitoids of LBAM are the bethylids (*Gonozius jacintae*), braconids (*Dolichogenidea tasmanica* and *Therophilus unimaculatus*), ichneumonids (*Australoglypta latrobei*, *Exochus* species and *Xanthopimpla rhopaloceros*) and chalcids (*Brachymeria rubripes*) (Suckling, Brockerhoff 2010). *Euplectrus agaristae* is a parasitoid of vine moth larvae (Bernard et al. 2006a).

Other moth larvae, including armyworm, cutworm and budworm, will be attacked by various wasp species. An unidentified species of braconid wasp has been recognised as a potential control for elephant weevil, *Orthorhinus cylindrirostris* (Thomson et al. 2007).

Metaphycus maculipennis is a common parasitoid of the grapevine scale insect, *Parthenolecanium persicae* (Rakimov et al. 2015). A specific strain of *Trichogramma carverae* has been isolated that parasitises flat LBAM eggs (rather than round eggs), and has been made available for biocontrol (Glenn, Hoffmann 1997).

Sensitivity to sprays: parasitoid wasps are particularly sensitive to high rates of sulphur (≥400 g/100 litres), clothianidin, carbaryl, methomyl, fipronil, indoxacarb, organophosphates, pyrethroids and spinosad (Thomson 2012).

Figure 45 wasp silk cocoon on grapevine. Image: Mary J Retallack

Delaying the release of *Trichogramma* wasps – until six days after spraying with sulfur – will reduce adverse effects on released organisms (Thomson et al. 2000).

Amazing fact

A novel interaction occurs between a parasitoid wasp, LBAM and a predatory mite species. The activity of *Dolichogenidea tasmanica* renders larval LBAM more susceptible to attack by the predatory mite, *Anystis baccarum* (Paull 2007).

4.1.5.2.2. Superfamily Chalcidoidea | Chalcid wasps

Description: these wasps are often metallic in colour.

Host: chalcid parasitoid hosts include Lepidoptera (butterflies and moths), Diptera (true flies), Coleoptera (beetles), Hemiptera (true bugs), other Hymenoptera, as well as two Orders of Arachnida and a Family of nematodes.

Figure 46 A chalcid parasitoid wasp. Image: Mary J Retallack

4.1.5.2.3. Superfamily Ichneumonoidea | Ichneumonid wasps | Family Braconidae | Braconid wasps

Description: small to medium size (1 to 8 mm in body length). Colour varies from red, orange, yellow, black, white and brown. The females of many species have extremely long ovipositors for laying eggs.

Host: parasitoid wasps are important biological control agents of pest species, including moths (eggs or larvae), scale insects, and other invertebrates (often host specific).

Figure 47 Ichneumonid parasitoid wasp (top). Image: Mary J Retallack

Figure 48 Braconid parasitoid wasp, Dolichogenidea tasmanica, *parasitising a light brown apple moth larva (middle). Images: Michael A Keller; braconid wasp, Aphidius species, parasitising aphids (bottom). Image: Mary J Retallack*

4.1.5.2.4. Superfamily Proctotrupoidea | Proctotrupoid wasps

Description: a Superfamily containing seven Families.

Figure 49 A proctotrupoid parasitoid wasp. Image: Mary J Retallack

4.1.5.2.5. Superfamily Tiphioidea | Family Tiphiidae | Tiphiid wasps

Description: some females are wingless (see Figure 50) and hunt for ground-dwelling beetle larvae.

Host: ground beetle larvae.

Figure 50 Tiphiid parasitoid wasp – male (top), and female (bottom). Image: Mary J Retallack

4.1.5.2.6. Superfamily Vespoidea | Vespoid wasp

Description: vespoid wasp females have antennae with 10 segments, while male antennae have 11 segments. Most species have fully developed wings, but some have reduced or absent wings in one or both sexes. As with other Aculeata (a taxonomic Infraorder), only the females are capable of stinging.

Host: caterpillars and spiders.

Figure 51 Vespoid predatory wasp (top right); 'orange potter wasp', Eumenes latreilli, *a vespoid predatory wasp, on Christmas bush (bottom right). Images: Mary J Retallack*

4.1.6. Order Hymenoptera | Ants

4.1.6.1. Family Formicidae | Ants

Origin: Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: ants possess mandibles for chewing. They have three distinct body segments and six slender legs.

Distinctive features: ants are distinct in their morphology from other insects, as they have elbowed antennae, and a strong constriction of their second abdominal segment into a node-like petiole (narrowing).

Prey: ants exploit many different food resources as direct or indirect herbivores, predators of various insects, and scavengers. Adult ants feed on liquids, but larvae will feed on processed solids. The majority of the liquid diet comes from sugar-rich secretions from plants, other invertebrates, or from their own larvae (which accept plant and animal tissue that is then regurgitated and presented in a liquefied form to the adults (Australian Museum 2019).

Mode of predation: ants prey on various insects and animals, collecting both live and dead invertebrates. They consume vast numbers of the eggs and larvae, as well as the adults, of insects and other invertebrates. Some species prey on small insects, and use their barbless stinger to kill insects by injecting venom.

Habitat: various – wherever they can find prey.

Breeding cycle: hatched eggs go through a larval and pupal stage before emerging as an adult. The average worker has a life expectancy of just over one year.

Significance to viticulture: omnivore ants are generalist feeders of a range of pest species. Meat ants, *Iridomyrmex* species, are some of the few predators that will consume black Portuguese millipedes (Crawford 2015).

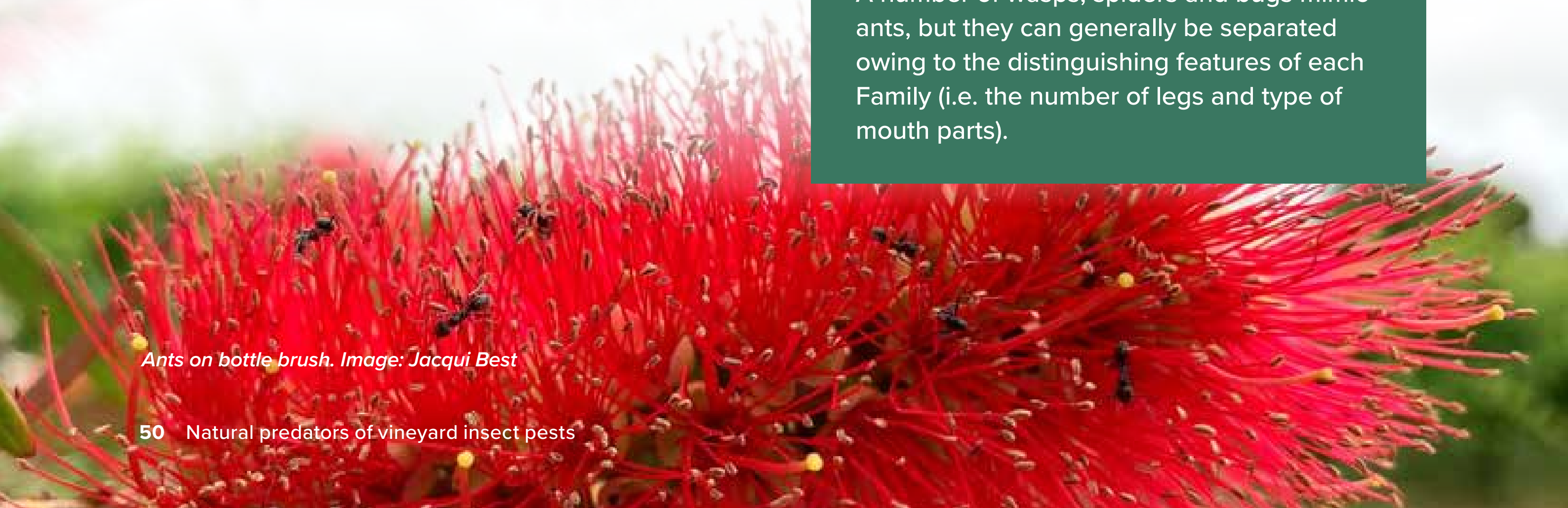
Figure 52 Jack jumper ant, Myrmecia pilosula*, on Christmas bush (top); an ant in leaf litter on the ground (bottom). Images: Mary J Retallack (top), Martin Stokes (bottom)*

Many ant communities form special partnerships with plants and other insects such as scales and mealybugs in vineyards. The ants protect and tend their partnership species, and in return they are supplied with sugar-rich honeydew secretions. This can prove problematic for control of pest species, as ants actively defend their partnership species to continue benefiting from the symbiotic relationship.

Sensitivity to sprays: ants are sensitive to chlorpyrifos, diazinon and permethrin. They have very high sensitivity to indoxacarb, clothianidin, fipronil, sulfoxaflor and organophosphates, as well as being highly sensitive to petroleum spray oil, chlorantraniliprole, spinosad and methomyl (CRDC 2019).

Amazing fact

A number of wasps, spiders and bugs mimic ants, but they can generally be separated owing to the distinguishing features of each Family (i.e. the number of legs and type of mouth parts).



Ants on bottle brush. Image: Jacqui Best

4.1.7. Order Neuroptera | Net-winged insects

4.1.7.1. Family Chrysopidae – *Mallada signata* | Green lacewing

Origin: native to Australia.

Distribution: widespread throughout south-eastern Australia (Atlas of Living Australia 2019).

Description: adults have a green body with two pairs of delicate transparent lace-like wings. They are approximately 12 mm in body length (not including wings). Larvae are brown with a wide mid-section that tapers towards the head and rear end. They have large piercing mandibles for capturing prey. Larvae range in size from 1 mm at emergence, up to 8 mm just before they pupate.

Distinctive features: adults have long antennae and prominent eyes, with wings folded over the back in an inverted 'V' shape. The larvae are also known as 'junk bugs' – as they have small spines on their backs, on which they impale the remnants of dead prey to help camouflage themselves from predators. Green lacewing adults are more active at night, and are slightly larger than brown lacewings, which are active during the day.

Prey: larvae are generalist predators and feed on soft-bodied insects such as thrips, scales, mites, mealybugs, moth eggs and small caterpillars. If food is in short supply, they may eat each other. Adults predominantly feed on honeydew, nectar and pollen.

Mode of predation: larvae have hollow, sickle shaped jaws that they drive into soft-bodied insects or eggs before sucking up their contents. Adults have mandibles for chewing prey.

Habitat: commonly found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and wallaby grasses, *Rytidosperma* species, during spring and summer (Retallack 2019).

Breeding cycle: females lay up to 600 eggs. Eggs are white, oval-shaped, and are suspended on silk stalks so that ants and newly hatched larvae do not consume the larvae as they emerge. Larvae pass through three moults over a fortnight before pupating inside a silken cocoon. Adults emerge after nine days and start laying eggs seven days after emergence. Adults live for three to four weeks.

Significance to viticulture: green lacewings can be purchased from commercial suppliers for release as biocontrol agents of light brown apple moth (LBAM), soft scale and mealybugs (Bernard et al. 2006b). They will be more likely to establish if there is a refuge of suitable nectar-producing trees and/or shrubs nearby.

Figure 53 Adult green lacewing, Mallada signata*, on grapevine (top); a 'junk bug' – a green lacewing larva with remnants of dead prey attached to small spines on its back (middle). Images: Mary J Retallack*

Figure 54 Green lacewing, Mallada signata*, larva (a 'junk bug') on grapevine (above left); green lacewing eggs (attached to silken stalks) on a grape bunch (above right). Images: Mary J Retallack*

Sensitivity to sprays: pesticides are toxic to lacewings; and some fungicides may be disruptive. Chlorpyrifos can persist for up to eight weeks; and along with lime sulphur, high rates of elemental sulphur and mancozeb are particularly damaging to lacewing populations (Thomson, Hoffmann 2007). Lacewings are very sensitive to carbaryl, methomyl and pyrethroids (Thomson 2012). They have very high sensitivity to chlorantraniliprole and spirotetramat, and high sensitivity to sulfoxaflor and clothianidin (CRDC 2019).

Amazing fact

Their silk is tougher than that produced by silkworms, and may be stretched up to six times further. The silk is used to create tiny stiff stalks to hold each egg (Weisman et al. 2008).

4.1.7.2. Family Hemerobiidae – Micromus tasmaniae | Brown lacewing or Tasmanian lacewing

Origin: native to Australia.

Distribution: widespread throughout south-western and south-eastern Australia (Atlas of Living Australia 2019).

Description: adults are brown in colour with two pairs of delicate hairy transparent lace-like wings, and long antennae. They are approximately 12 mm in body length (not including wings). Larvae are mottled brown in colour with a long body, which is wider in the middle and tapers at each end. They have large piercing mandibles for capturing prey. Larvae are approximately 7 to 9 mm in length.

Distinctive features: brown lacewing larvae are longer and thinner than those of green lacewing, and do not carry debris on their backs like green lacewing larvae.

Prey: both adults and brown lacewing larvae are predaceous. They are generalist predators and feed on soft-bodied insects such as thrips, scales, mites, aphids, mealybugs, moth eggs and small caterpillars.

Mode of predation: larvae have hollow, sickle-shaped jaws that they drive into soft-bodied insects or eggs before sucking up the contents. Adults have mandibles for chewing prey.

Habitat: commonly found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and low-growing vegetation such as wallaby grasses, *Rytidosperma* species (Retallack 2019). Wallaby grasses are important breeding sites for brown lacewings (Wood et al. 2011). Lacewings are observed abundantly during spring and summer (Retallack 2019). Along with spiders, they are often the most abundant predators present in early spring, reflecting their adaptation to the cold (New 1984).

Breeding cycle: eggs are brown or white, oblong, and laid on the underside of leaves (without stalks). The first instar larva hatches from the egg, and as the larva grows, it moults and goes through another two instars taking about seven days. When mature, the last instar larvae move into leaf litter and spin a cocoon to pupate. When adults emerge from the pupal stage, they attempt to find a mate. They are able to breed all year.

Significance to viticulture: brown lacewings are important biocontrol agents of light brown apple moth (LBAM), soft scale and mealybugs (Bernard et al. 2006b). They will be more likely to establish if there is a refuge of suitable nectar producing trees and/or shrubs nearby.

Figure 55 Adult brown lacewing, Micromus tasmaniae *(top); brown lacewing larva (middle). Images: Mary J Retallack*

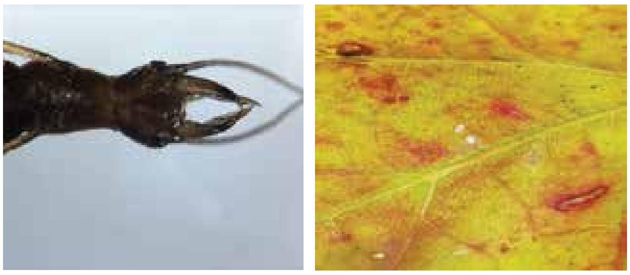


Figure 56 Brown lacewing larva (bottom left), lacewing eggs (bottom right). Images: Mary J Retallack (left), Kerry-Anne March (right)

Sensitivity to sprays: pesticides are toxic to lacewings; and some fungicides may be disruptive. Chlorpyrifos can persist for up to eight weeks; and along with lime sulphur, high rates of elemental sulphur and mancozeb are particularly damaging to lacewing populations (Thomson, Hoffmann 2007).

Lacewings are very sensitive to carbaryl, methomyl and pyrethroids (Thomson 2012). They have very high sensitivity to chlorantraniliprole and spirotetramat, and high sensitivity to sulfoxaflor and clothianidin (CRDC 2019).

Amazing fact

Brown lacewing adults are active during the day, and are smaller than green lacewings, which are more active at night.

4.1.7.3. Family Mantispidae | Mantid lacewings or mantisflies

Origin: various, common throughout the world, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: approximately 5 to 25 mm in body length, with a wing span of 5 to 30 mm. They have four membranous wings which may sometimes be patterned, but are usually clear. Mostly brownish in colour, with green, yellow and sometimes red hues. The first segment of the thorax (pronotum) is elongated into a distinct 'neck' shape.

Distinctive features: they are characterised by having raptorial shaped forelegs, similar to a praying mantis. They have clear membranous wings (whereas praying mantis do not), and their antennae are short and sometimes thickened.

Prey: adults eat small insects and spiders, caught with their raptorial forelegs. Depending on the Family, larvae may feed on eggs within the egg sacs of spiders or juveniles of Coleoptera (beetles), Lepidoptera (moths), Hymenoptera (wasps, bees or ants) and Diptera (flies).

Mode of predation: their spiny raptorial front legs are modified to catch small insect prey, and are very similar to the front legs of the praying mantis. However, the pincers lack footpads, and are not used for walking. Mantid lacewings are most active at night.

Habitat: found in the canopy of grapevines, Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*, during spring and summer (Retallack 2019). They are also found on fragrant saltbush, *Chenopodium parabolicum* (Wood et al. 2011).

Breeding cycle: females lay eggs in batches of small stalked eggs, often hundreds at a time. Hatching larvae search for a spider egg sac and burrow inside. There are three larval instars. The first instar is mobile, while the second and third instars are quite sedentary.

Pupation occurs in the spider egg sac once all the spider eggs are consumed, prior to the mantid lacewing emerging as an adult.

Significance to viticulture: mantid lacewings are predators of a range of vineyard pests, including beetles and moths.

Sensitivity to sprays: pesticides are toxic to lacewings; and some fungicides may be disruptive. Chlorpyrifos can persist in toxicity for up to eight weeks; and along with lime sulphur, high rates of elemental sulphur and mancozeb are particularly damaging to lacewing populations (Thomson, Hoffmann 2007).

Lacewings are very sensitive to carbaryl, methomyl and pyrethroids (Thomson 2012). They have very high sensitivity to chlorantraniliprole and spirotetramat, and high sensitivity to sulfoxaflor and clothianidin (CRDC 2019).

Figure 57 A mantid lacewing (top). Image: Mary J Retallack

Figure 58 Mantid lacewings on grapevine (bottom). Images: Liz Riley (left), Mary J Retallack (right)]

Amazing fact

Mantid lacewings are active, predatory hunters, but are cumbersome fliers. They are often confused with the praying mantis, as they also have raptorial forelegs. Mantid lacewings can be distinguished by their wings, which unlike mantises, are always present.

The wings of mantid lacewings are clear, held tent-like over their body (at rest) and possess forked veins along the wing margin (Australian Museum 2019).

4.1.8. Order Dermaptera | Earwigs

4.1.8.1. Suborder Forficulina | Family Forficulidae | Earwigs

Figure 59 Male European earwigs, Forficula auricularia, *on grapevine (top) and (middle). Images: Mary J Retallack*

Figure 60 Female European earwig, Forficula auricularia *(above left); common brown earwig,* Labidura truncate *(above right). Images: Mary J Retallack (above left), Michael Nash (above right)*

Origin: various, common throughout the world, including Australia. Some species are native to Australia, such as the common brown earwig, *Labidura truncata*.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: approximately 12 to 15 mm in body length. Earwigs have an elongated and flattened, or cylindrical, body. They can be winged or wingless. The abdomen is long and flexible. The two forcep-like 'cerci' on the end of the abdomen are heavily sclerotised (hardened), and vary in shape and size between species. Earwigs come in a range of colours, including reddish brown, dark brown and black.

Distinctive features: females can be readily distinguished from males as they are usually smaller, have simple forceps, and eight visible abdominal (hind-body) segments (as opposed to males, which have ten) (Australian Museum 2019).

Prey: earwigs are mostly omnivorous, eating a wide variety of live and decaying plant and animal material.

Mode of predation: the forceps are used for defence, as well as catching and carrying prey. Earwigs have chewing mouthparts, and are most active at night.

Habitat: they may be found in protected, moist environments such as leaf litter and debris on the ground. Earwigs are often found in association with grapevines and wallaby grasses, *Rytidosperma* species, throughout the entire year (Retallack 2019). They are also found on fragrant saltbush, *Chenopodium parabolicum* (Wood et al. 2011).

Breeding cycle: females dig a short burrow in the ground beneath leaf litter and debris, where they lay their eggs as well as defend against intruders. When the nymphs hatch from eggs, they resemble the adult form. Nymphs moult four to five times before becoming adults.

Significance to viticulture: the European earwig is an important omnivorous predator of light brown apple moth (LBAM) in vineyards (Frank et al. 2007). They may cause minor, isolated damage to newly emerging growth just after budburst – however, any risk is likely to be offset by the biocontrol benefits earwigs provide in vineyards, especially in the period leading up to harvest when chemical control options are limited (Retallack 2019).

Sensitivity to sprays: earwigs are particularly sensitive to broad-spectrum insecticides, including chlorpyrifos and pyrethroids.

Amazing fact

The common brown earwig, *Labidura truncata*, is known to eat the European earwig (Crawford 2015).

4.1.9. Order Mantodae | Mantises

Origin: various, common throughout the world, including Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: coloured green or brown with an elongate body shape. Females are usually larger than males. The eyes are large, bulbous and well separated. At rest, the wings (when present) are held flat over body, or curved around the abdomen, overlapping each other, with the hindwing hidden. Approximately 10 to 120 mm in body length.

Distinctive features: praying mantises – unlike mantisflies – often lack wings, or if present, the wings are leathery and held flat over their body. Moreover, they have a triangular head, and their hindwing folds away like a hand fan.

Prey: they are predators, eating mostly arthropods, but have been known to eat small vertebrates.

Mode of predation: praying mantises are mostly 'ambush' predators, but a few ground-dwelling species are found actively pursuing their prey. They are carnivores with powerful chewing mouthparts. Forelegs are always raptorial, that is, bearing rows of sharp teeth that are used for clasping prey.

They are experts at camouflage – many have cryptic colouration and structural modifications that help them blend in with their surroundings. They also tend to spend a lot of their time motionless, with their forelegs outstretched awaiting prey. They are active during the day and night.

Habitat: praying mantis are found on vegetation such as flowers, tree trunks, tall grasses, fragrant saltbush, *Chenopodium parabolicum* (Wood et al. 2011), grapevines and prickly tea-tree, *L. continentale* (Retallack 2019). There are also some species that live on the ground.

Breeding cycle: they normally live for about a year. In cooler climates, the adults lay eggs in autumn, then die. The eggs are protected by their hard capsules, and hatch in spring

figure 61 Praying mantises (top) and (middle left and bottom right). Images: Mary J Retallack

Figure 62 Praying mantises – showing raptor-like legs (middle right). Images: Mary J Retallack

Significance to viticulture: praying mantis are generalist predators of a range of vineyard pests.

Sensitivity to sprays: collateral damage to mantis populations will occur if broad-spectrum insecticides are used.

Amazing fact

Females sometimes practice cannibalism, eating their mates after copulation.

Image: Craig Arnold

4.1.10. Order Orthoptera | Katydids

4.1.10.1. Suborder Ensifera | Family Tettigoniidae | Katydids or bush crickets

Origin: native to Australia.

Distribution: widespread throughout Australia (Atlas of Living Australia 2019).

Description: katydids are grasshopper-like insects that are experts at camouflage. They use behaviour or colouration patterns, as well as special body forms, to help them blend in with their surroundings. They are most active at night; and are approximately 10 to 60 mm in body length.

Distinctive features: katydids may be distinguished from grasshoppers by the length of their filamentous antennae, which may exceed their own body length; whereas grasshopper antennae are always relatively short and thickened.

Prey: the diet of most katydids includes leaves, flowers, bark and seeds – but many species are exclusively predatory, feeding on other insects, snails, or even small vertebrates such as snakes and lizards!

Mode of predation: some katydids have spines on different parts of their bodies that are used to confine their prey, by making a temporary cage above their mouthparts.

Habitat: found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, during spring and summer (Retallack 2019).

Breeding cycle: the lifespan of a katydid is about a year. Females lay their eggs at the end of summer beneath the soil or in plant stem holes.

The eggs are typically oval, and laid in rows on the host plant. Eggs hatch into nymphs, which moult five times before adulthood. There is one generation per year.

Significance to viticulture: some species of katydids are predators of insect pests and their eggs.

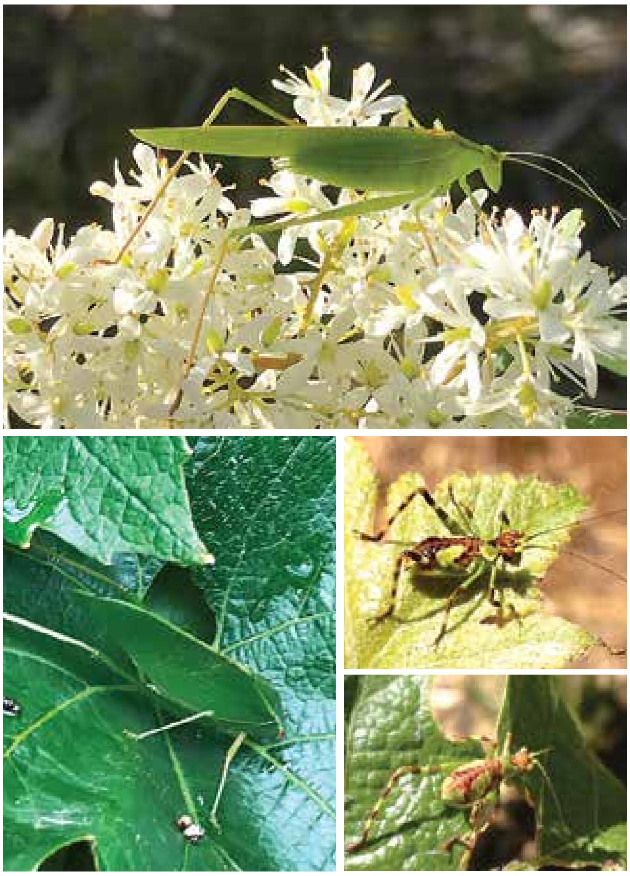


Figure 63 Adult katydid on grapevine (bottom left), and on Christmas bush (top). Images: Mary J Retallack

Figure 64 Katydid nymphs on grapevine (middle and bottom right). Images: Mary J Retallack

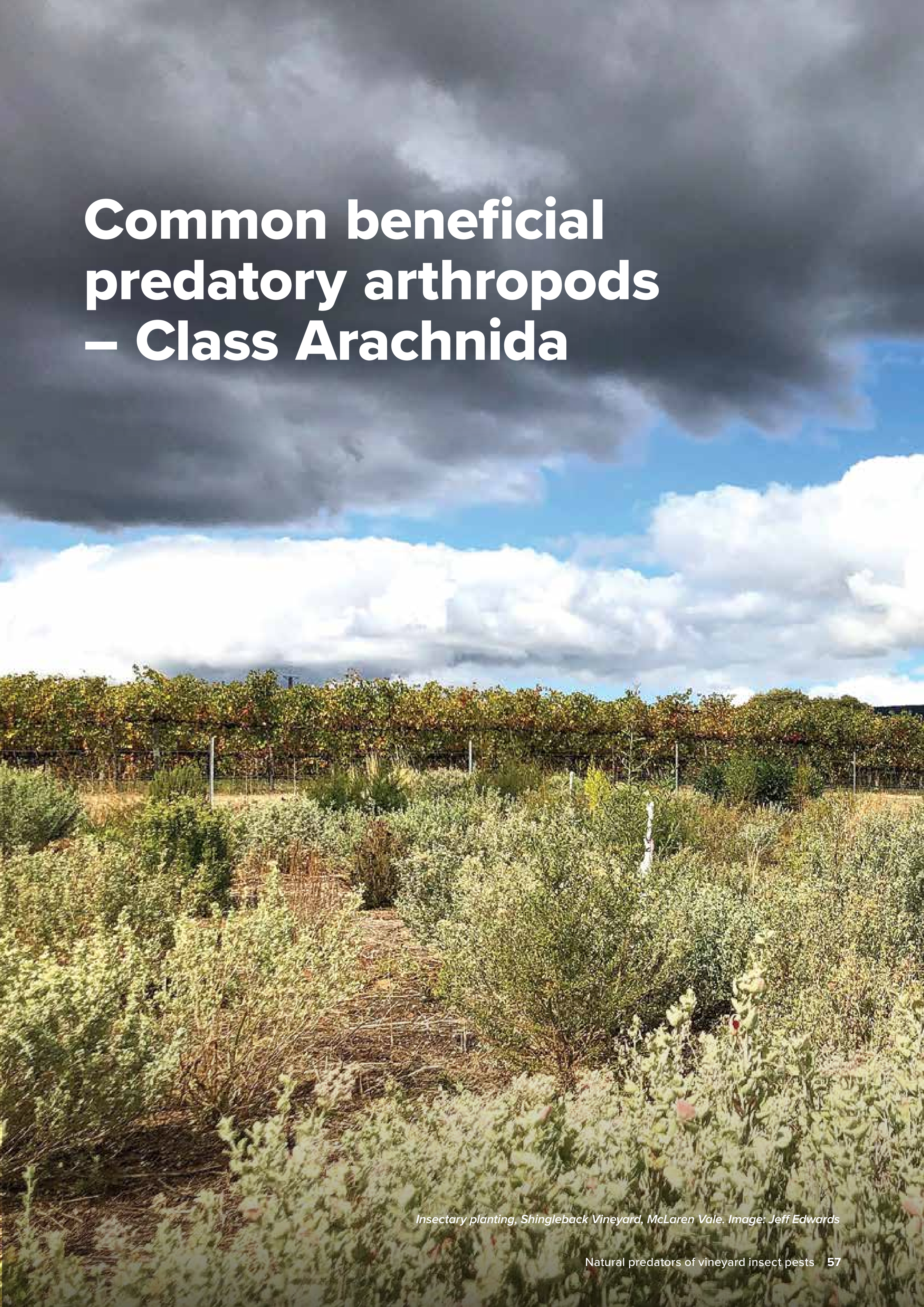
Sensitivity to sprays: collateral damage to katydid populations will occur if broad-spectrum insecticides are used.

Amazing fact

Many katydids exhibit mimicry and camouflage, commonly with shapes and colours that are similar to leaves!

Chalcid wasp larvae feeding on a grapevine moth larva. Image: Kerry-Anne March

Common beneficial predatory arthropods – Class Arachnida



Insectary planting, Shingleback Vineyard, McLaren Vale. Image: Jeff Edwards

4.2. Class Arachnida

4.2.1. Order Mesostigmata | Mites

4.2.1.1. Family Phytoseiidae | Predatory mites

Origin: various, worldwide distribution.

Distribution: found throughout south-eastern Australia (Atlas of Living Australia 2019).

Description: mites are tiny – ranging from less than 0.5 to 2 mm in body length – and just visible to the naked eye.

Distinctive features: the predatory mite *Phytoseiulus persimilis* was originally introduced from Chile as a biological control agent. They are red, whereas other mites are translucent and harder to see without the aid of magnification.

Prey: predatory mites readily consume a range of thrips and pest mite species. They may also feed on plant exudates and pollen.

Mode of predation: fast-moving predators that are most active when temperatures are between 20 to 30°C.

Habitat: commonly found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, during spring and summer (Retallack 2019).

Breeding cycle: predatory mites reproduce rapidly when prey is readily available. They postpone or delay egg production when prey is scarce. At optimum temperatures, Phytoseiidae species can develop from egg to adult in seven days and live up to a month. A well-fed female lays about 50 eggs in her lifetime.

Significance to viticulture: predatory mites contribute to the control of a range of vineyard mite pests. The predatory mite, *Phytoseiulus persimilis*, is commonly observed on grapevines, and contributes to the control of a range of pest mites.

The predatory mites, *Euseius victoriensis* ('Victoria') and *Typhlodromus doreenae* ('Doreen'), contribute to control of grape bud mite, *Colomerus vitis*, blister mite, *Colomerus vitis*, rust mite, *Calepitrimerus vitis*, and bunch mite, *Brevipalpus lewisi.*

Figure 65 Predatory mite on Christmas bush. Image: Mary J Retallack

The mite species, *Anystis baccarum*, is a predator of the eggs and crawlers of soft scale insects (Bernard et al. 2004; Winter et al. 2018). A predatory thrips, *Haplothrips victoriensis*, also feeds on rust mite (Bernard et al. 2006b).

The easiest way to distinguish between the species of mites present on grapevines is by the damage they cause. Microscopic magnification of 40 times is necessary to directly identify different mite specimens. Predatory mites are used as biological control agents of common mite pests – and they can be purchased commercially for release.

Sensitivity to sprays: predatory mites are particularly sensitive to chemical sprays, including the active constituents emamectin benzoate and mancozeb (Bernard et al. 2004), spinosad (from direct overspray and residue), wettable sulfur (≥400 g/100 litres) and pyrimethanil (Bernard et al. 2010).

Chemical residues toxic to predatory mites must have time to degrade before mites are released for biological control. Synthetic pyrethroids and some organophosphates, for example, may need up to eight weeks to break down (Bugs for Bugs 2019).

Amazing fact:

The *Phytoseiulus* mite is an introduced biological control agent that can consume up to seven adult pest mites or several dozen of their eggs in a day.

Kangaroo grass. Image: Jeff Edwards

4.2.2. Order Araneae | Spiders

There are at least 17 different families of spiders found in and around South Australian vineyards.

These include Arkyidae (triangular spiders), Araneidae (orb weaver spiders), Deinopidae (net-casting spiders), Dysderidae (woodlouse or slater-hunter spiders), Gnaphosidae (ground spiders), Linyphiidae (money spiders), Lycosidae (wolf spiders), Oxyopidae (lynx spiders), Philodromidae (philodromid crab spiders), Pholcidae (cellar spiders), Salticidae (jumping spiders), Sparassidae (huntsman spiders), Tetragnathidae (long-jawed spiders), Theridiidae (claw-footed spiders), Thomisidae (crab spiders), Idiopidae (trapdoor spiders) and Zodariidae (ant spiders).

The most commonly observed Families and species are presented below.

4.2.2.1. Family Araneidae – *Celaenia excavata* | Bird-dropping spider

Origin: native to Australia.

Distribution: commonly found throughout south-western, southern, eastern and north-eastern Australia – mainly in coastal areas (Atlas of Living Australia 2019).

Description: males are much smaller than females (approximately 2.5 mm in body size compared to approximately 12 mm).

Distinctive features: the spider derives its name from mimicking bird droppings to avoid predators, mainly birds.

Prey: bird-dropping spiders are generalist feeders and consume a wide range of prey, including scale insects, and, in the case of *Celaenia excavata*, male moths.

Mode of predation: web-based ('sedentary'). The spider stays motionless on their web during the day, only hunting at night. They hang down from a single silk thread and release a pheromone which mimics the sex smells released by female moths. When a male moth comes near, the spider will capture it with its powerful front legs (Henderson 2018).

Habitat: commonly found in the canopy of grapevines, and surrounding native vegetation, including prickly tea-tree, *L. continentale*, during late spring and summer (Retallack 2019).

Breeding cycle: females lay up to 13 egg sacs, with about 200 eggs in each, strung together with strong silk threads.

Figure 66 Adult bird-dropping spider on grapevine (top); adult bird-dropping spider hanging from a silken thread waiting for prey in a vineyard (bottom left). Images: Mary J Retallack

Figure 67 Adult bird-dropping spider and egg sacs on prickly tea-tree (middle and bottom right). Images: Mary J Retallack

Significance to viticulture: the bird-dropping spider contributes to the control of moths, including light brown apple moth (LBAM).

Sensitivity to sprays: collateral damage to spider populations will occur if broad-spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).

Amazing fact:

Their bodies look like unappetising bird droppings. They are also known as the 'death's head spider', as body markings may resemble the shape of a skull (Australian Museum 2019).

4.2.2.2. Family Araneidae | Orb-weaver spiders

Origin: native to Australia.

Distribution: commonly found throughout Australia (Atlas of Living Australia 2019).

Description: females are approximately 20 to 30 mm, while males are 14 to 20 mm in size.

Distinctive features: garden orb-weavers come in many shapes and sizes. They have a roughly triangular abdomen, often with reddish-brown or grey colouring. Conversely, the 'speckled orb-weaver' is green with white spots. Orb-weavers crouch head-down in a distinctive compact position when they are lying in wait for prey.

Prey: spiders are generalist feeders and consume a wide range of prey. Orb-weavers specialise in capturing flying insects in their web.

Mode of predation: web-based ('sedentary'). Orb-weavers make a sticky, wheel-shaped orb web to capture flying insects. Webs are placed between openings of trees and shrubs, as well as between grapevines in vineyards. They float a line of silk thread on the wind across an adjoining surface, and secure the line in the centre forming a 'Y' shape. They then construct their web, which comprises spirals of non-sticky silk, followed by a final layer of sticky silk. Prey are stunned by a quick bite, and then wrapped in silk.

Habitat: commonly found in the canopy of grapevines and surrounding native vegetation, including Christmas bush, *B. spinosa*, prickly tea-tree, *L. continentale*, and, less often, on wallaby grasses, *Rytidosperma* species. They are most active throughout spring and summer (Retallack 2019).

Breeding cycle: orb-weavers live for up to 12 months. Females lay eggs in late summer to autumn, which are encased in a fluffy silken cocoon attached to foliage. During autumn, spiderlings hatch and disperse by ballooning (extending a silken thread into the wind and floating on the breeze). They overwinter in vegetation, and start to grow more rapidly during spring, maturing in summer. The cycle starts again with the adults laying eggs, and then dying in autumn or early winter (Australian Museum 2019).

Significance to viticulture: orb-weavers contribute to the control of flying pest insects, as well as a range of other arthropod pests, including scale insects (Thomson et al. 2007).

Figure 68 Garden orb-weaver, Eriophora *species – hanging between grapevine rows (top), and on grapevine (middle). Images: Mary J Retallack*

Figure 69 Garden orb-weaver, Eriophora *species, on grapevine (bottom left), and speckled orb-weaver,* Araneus circulissparsus *(bottom right). Images: Mary J Retallack*

Sensitivity to sprays: collateral damage to spider populations will occur if broad spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).

Amazing fact

Orb-weavers build a new web each evening. They consume the old web, rest, and then spin a new web in the same general location. This keeps the web free of debris that may otherwise accumulate.

4.2.2.3. Family Arkyidae – *Arkys* species | Triangular spiders

Origin: native to Australia.

Distribution: commonly found throughout south-western, southern, eastern and north-eastern Australia – mainly in coastal areas (Atlas of Living Australia 2019).

Description: body size of approximately 6 mm, with a brightly coloured triangular-shaped abdomen.

Distinctive features: as the common name suggests, these spiders have a triangular or heart-shaped abdomen, which is often brightly coloured with a combination of red, yellow-orange, black or white markings. The two sets of front legs are enlarged, covered in spines, and curved to catch prey (Australian Museum 2019).

Prey: spiders are generalist feeders and consume a wide range of prey, including thrips.

Mode of predation: an ambush ('active') predator. They are thought to be mostly nocturnal, but are also present during the day.

Habitat: found in the canopy of grapevines and surrounding native vegetation, including prickly tea-tree, *L. continentale*, Christmas bush, *B. spinosa*, and wallaby grasses, *Rytidosperma* species, and are most prevalent throughout spring and summer (Retallack 2019).

Breeding cycle: in late summer, females produce a small egg sac that can contain up to 50 eggs (Australian Museum 2019).

Significance to viticulture: a generalist feeder of a wide range of pests, including light brown apple moth (LBAM) and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage to spider populations will occur if broad spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).

Figure 70 An adult triangular spider (top); a triangular spider eating a 'western flower thrips' (bottom). Images: Mary J Retallack

Amazing fact

Triangular spiders have been placed in several different Families since their original description, and the debate is still continuing as to where they fit in taxonomically in relation to other spiders.

They were elevated from a Subfamily of Araneidae (orb weavers) to their own Family Arkyidae (triangular spiders) in 2017 (World Spider Catalog 2019).

4.2.2.4. Family Lycosidae | Wolf spiders

Origin: native to Australia

Distribution: wolf spiders are found throughout Australia – with 'garden wolf spiders' commonly found in southern and eastern Australia (Atlas of Living Australia 2019). This wide distribution is aided by their ability to disperse aerially as spiderlings by 'ballooning' over large distances.

Description: they are robust, agile hunters that live on the ground, in leaf litter or burrows, with a body size of approximately 10 to 35 mm. Wolf spiders can build a camouflaged trapdoor/lid (with or without a weak silken hinge) for their burrow.

Distinctive features: body colours are typically brown or grey with variegated patterns, often with radiating lines on the front of the body and scroll-like patterns on the abdomen (Australian Museum 2019).

Prey: spiders are generalist feeders, consuming a wide range of prey.

Mode of predation: they are hunters (and so are 'active' predators). More specifically, they are solitary hunters that do not spin webs. Wolf spiders are most active at night and have excellent eyesight.

Habitat: they are found in abundance on wallaby grasses, *Rytidosperma* species, and, less so, in the canopy of grapevines and surrounding native vegetation, including prickly tea-tree, *L. continentale*, and Christmas bush, *B. spinosa*. They are active all year round, but more plentifully during spring and summer (Retallack 2019).

Breeding cycle: the egg sac is constructed from white papery silk. Uniquely, the female carries the egg sac by attaching it to her spinnerets using silk, so that she can carry her unborn young with her.

When the spiderlings hatch, they are carried around on the back of the female until they are ready to disperse by ballooning in the air, or by dispersing on the ground. They live for up to two years (Australian Museum 2019).

Significance to viticulture: they are generalist feeders of a wide range of pests, including light brown apple moth (LBAM) and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage to spider populations will occur if broad spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).

Figure 71 A 'garden wolf spider', Tasmanicosa *species, eating a 'lynx spider' (top left); an especially well-camouflaged female 'garden wolf spider',* Tasmanicosa godeffroyi, *with an egg sac (bottom). Images: Mary J Retallack*

Amazing fact

Their characteristic eye formation is four large eyes arranged in a square on top of the head, with four smaller eyes in a row at the front. If you shine a torch light on them at night, the light will reflect from the their eyes creating a greenish-yellow glow that is easily observed.

4.2.2.5. Family Salticidae | Jumping spiders

Origin: native to Australia.

Distribution: jumping spiders are found throughout Australia (Atlas of Living Australia 2019).

Description: jumping spiders are small (body size of approximately 3 to 12 mm), and come in a diverse range of colours and sizes.

Distinctive features: they have a distinctive eye pattern with four sets of eyes, including a prominent set at the front of their box shaped head, which are particularly large and appear to be located on a flat surface. Collectively their eyes provide 360-degree vision.

Prey: they are carnivorous feeders, consuming a wide range of prey, including insects twice their own size, and are also known to consume nectar.

Mode of predation: they are agile hunters (and so are 'active' predators) – being active during the day. They also have excellent eyesight, which is used to calculate distance, as well as track, stalk and jump on their prey through being propelled by strong back legs. They can jump several times the length of their bodies.

As they jump, they tether themselves to a silk dragline to stop themselves from falling. The dragline is impregnated with pheromones that play a role in social and reproductive communication. Once prey is captured, it is immobilised by the spider biting and injecting rapidly-acting venom.

Habitat: found in a wide range of habitats, including in the canopy of grapevines and surrounding native vegetation such as prickly tea-tree, *L. continentale*, and Christmas bush, *B. spinosa*. They are prevalent throughout late-spring and summer (Retallack 2019).

Breeding cycle: the female builds a silk case around her eggs, often standing guard until they hatch.

Significance to viticulture: a generalist feeder of a wide range of insect pests, including light brown apple moth (LBAM) and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage to spider populations will occur if broad spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).




Figure 72 Jumping spiders on grapevine (top and bottom left). Images: Mary J Retallack

Figure 73 Jumping spiders – Helpis species (middle and bottom right). Images: Mary J Retallack

Amazing fact

Peacock spiders are also part of the Salticidae (jumping spider) Family. They have elaborate mating rituals; with the males being brightly coloured.

To find out more, a video can be viewed online of a male *Maratus speciosus* dancing to impress a prospective mate **https://youtu.be/v3HlwwJG85c**

They lift their brightly coloured lateral flaps, while tilting the abdomen upwards, resulting in a spectacular display. Brightly coloured peacock spiders are also found in South Australia.

4.2.2.6. Family Sparassidae | Huntsman spiders

Origin: native to Australia and many other parts of the world.

Distribution: found throughout Australia (Atlas of Living Australia 2019).

Description: huntsman spiders are large, long-legged spiders, with a body length of up to 20 mm, and a leg span of up to 150 mm. Their upper surfaces tend to be brown or grey.

Distinctive features: in addition to their size, huntsman spiders have joints twisted such that they spread their legs out forwards, as well as laterally, in a crab-like fashion.

Prey: spiders are generalist feeders, consuming a wide range of prey.

Mode of predation: a hunter (an 'active' predator). As their name suggests, huntsman spiders are known for their speed and mode of hunting. They use venom to immobilise prey. Their diet consists primarily of insects and other invertebrates and, occasionally, small skinks and geckos.

Habitat: found living under shelter, including loose bark on trees, in crevices, on rock walls, in logs, under rocks, as well as in the canopy of grapevines and surrounding native vegetation, including prickly tea-tree, *L. continentale*, and Christmas bush, *B. spinosa*. They are most prevalent throughout spring and summer (Retallack 2019).

Breeding cycle: females lay up to 200 eggs in an egg sac of white papery silk, place it under bark or a rock, and then stand guard over it without eating for up to three weeks. Newly emerged spiderlings are pale, and undergo several moults, eventually hardening and colouring into a darker brown, and then dispersing. They may live up to two years or more (Australian Museum 2019).

Significance to viticulture: a generalist feeder of a wide range of insect pests, including light brown apple moth (LBAM) and scale insects (Thomson et al. 2007).

Sensitivity to sprays: collateral damage to spider populations will occur if broad spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).

Figure 74 Huntsman spider (top); huntsman spider eating a scale insect (middle). Images: Mary J Retallack

Figure 75 Huntsman spiders (bottom). Images: Mary J Retallack

Amazing fact

Huntsman spiders are also known as 'giant crab spiders', owing to their appearance. They are known as 'wood spiders', because they live in woody places.

4.2.2.7. Family Thomisidae | Flower crab spiders

Origin: native to Australia.

Distribution: commonly found throughout Australia – mainly along southern and eastern coastal areas (Atlas of Living Australia 2019).

Description: flower crab spiders come in many shapes and sizes. Body size ranges from approximately 3 to 12 mm. All four pairs of legs curve forward in a crab-like fashion, hence the name crab spiders. They are frequently found in association with flowers, and are often well camouflaged. They are most frequently yellow, white, green or brown, and some are the same colour as the petals of the flowers they occupy.

Distinctive features: crab spiders are distinguished by their front four legs, which are very long and powerful.

Prey: Thomisid spiders are diurnal; and primarily eat bees, butterflies, flies and beetles. They are territorial, and often there is only one spider per flower – sitting in wait for prey until the petals wither, before moving to another flower.

Mode of predation: they are 'ambush' predators. Thomisids are foliage and flower dwellers. They depend on their camouflage for protection, as well as to ambush their prey.

Rather than constructing webs, they wait until the moment they can use their spiny front legs to capture prey, and then quickly bite it on the head area, injecting venom that rapidly immobilises their meal. Venom and digestive juices liquefy the insect's internal tissues, which the spider then consumes, leaving the shell behind (Australian Museum 2019).

Habitat: Flower crab spiders are commonly found on the flowers of Australian native plants such as grevilleas, wattles, Christmas bush, *B. spinosa*, and prickly tea-tree, *L. continentale*.

They are also found in vineyards, being prevalent in late spring and early summer (Retallack 2019). They seek refuge under flowers or leaves at night.

Breeding cycle: after mating, females conceal their eggs in woolly egg sacks, within a refuge of foliage, which may be folded over to protect the eggs. The young continue to develop during winter and spring. The adult female feeds insects to the developing spiderlings, and may even be eaten by her young if food is scarce!

Significance to viticulture: a generalist feeder of a wide range of pests, including light brown apple moth (LBAM) and scale insects (Thomson et al. 2007).

Figure 76 'Milky flower spider', Zygometis *species (top); 'flower crab spider',* Misumena *species (middle). Images: Mary J Retallack*

Figure 77 'Red-spotted slender crab spider', Cetratus rubropunctatus *(bottom left); 'crab spider', Cymbacha species (bottom right). Images: Mary J Retallack*

Sensitivity to sprays: collateral damage to spider populations will occur if broad spectrum insecticides are used. Spiders are particularly sensitive to mancozeb (Thomson et al. 2007), carbaryl, methomyl, organophosphates and pyrethroids (Thomson 2012).

Amazing fact

Some species of Thomisids can undergo slow changes in colour in order to better blend into their background (Australian Museum 2019).

4.2.3. Order Pseudoscorpiones | False scorpions

Origin: various, worldwide distribution.

Distribution: commonly found throughout Australia (Atlas of Living Australia 2019).

Description: false scorpions are small arachnids with a flat, pear-shaped body, and pincers that resemble those of scorpions. They are approximately 2 to 8 mm in body length. The abdomen is made up of twelve segments, each protected by plates. The colour of the body can be yellowish-tan to dark-brown, with the paired claws often a contrasting colour.

Distinctive features: the abdomen is short and rounded at the rear, rather than extending into a segmented tail and stinger like true scorpions.

Prey: they prey on small invertebrates, including moth larvae, beetle larvae, ants, mites and small flies.

Mode of predation: the pedipalps (claws) generally consist of an immobile 'finger', with a separate movable finger controlled by an muscle. A venom gland and duct are usually located in the mobile finger, and the venom is used to capture and immobilise prey. During digestion, pseudoscorpions pour a mildly corrosive fluid over the prey, then ingest the liquefied remains!

Habitat: commonly found in leaf litter and on grapevines in early spring (Retallack 2019).

Breeding cycle: fertilised eggs are laid into a brood-sac, which remains attached to the female, and within which the embryos are nourished. After hatching, they moult three times before becoming an adult.

Significance to viticulture: a generalist feeder of a wide range of pests.

Sensitivity to sprays: collateral damage to false scorpion populations will occur if broad spectrum insecticides are used.

Figure 78 False scorpions (top and middle). Images: Rose Fletcher (top), Kari Dawson (middle)

Figure 79 False scorpion bottom. Image: Mary J Retallack

Amazing fact:

Even though false scorpions resemble scorpions, they are not closely related.

Pollinators

Blue-banded bee. Image: Jeremy Gramp

5. Pollinators

5.1. Class Insecta

5.1.1. Order Hymenoptera

5.1.1.1. Superfamily Apocrita | Honey and Australian native bees

Origin: honey bees, various; Australian native bees, Australia

Distribution: honey bees and Australian native bees are found throughout Australia (Atlas of Living Australia 2019).

Description: bees have hairy, stout or elongate bodies, constricted at the 'waist'. Antennae are threadlike and distinctly elbowed, with the first segment much larger than the others. The eyes are large to very large, with two pairs of membranous wings.

Honey bees are usually brown with a banded dull-yellow and brown abdomen. The head, thorax and abdomen are densely covered in hair. The legs and around the eyes are also hairy; and they have a barbed sting. They are approximately 13 to 16 mm in body length.

These highly social insects live in large hives dominated by a single queen. The queen is larger than the worker bees or the male drones, and is responsible for egg laying, as well as for controlling the hive using pheromones. The majority of the hive is made up of worker bees that build and maintain the hive, as well as collect nectar and pollen to feed the developing bee larvae (Australian Museum 2019). Bees are key pollinators of many native and horticultural plant species.

Australian native bees can look superficially similar to honey bees. The only native bees to form large social hives are the stingless bees (*Trigona* and *Austroplebia*). These bees are dark coloured, and much smaller (at less than 5 mm in length) than honey bees.

Solitary native bees are not aggressive, and do not have a barbed sting (Australian Museum 2019). There are an incredible 1,700 species of native bees, and approximately 50 species are found on agricultural crops.

Other pollinators include flies, wasps, moths, butterflies and beetles.

Diet: bees forage on the flowers of many different native and introduced plant species. The majority are pollen or nectar feeders. They are not predators.

Buzz pollination: some native bees use a special pollination technique called 'buzz pollination'. The 'blue-banded bee', for example, bangs its head on the flower's anthers 350 times a second to release the pollen (Switzer et al. 2016)!

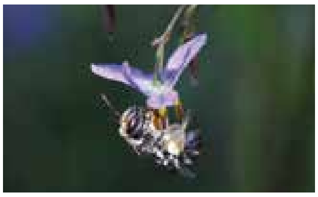


Figure 80 Honey bee on Christmas bush (top); native nomia bee, Lipotriches (Austronomia)*, foraging a native lily (middle left). Images: Mary J Retallack (top), J Gramps (middle left)*

Figure 81 'Blue-banded bees', Amegilla *species, utilising a native hop* goodenia *flower (bottom left); a fine-looking 'bee hotel', providing habitat for native bees and insects (bottom right). Images: Jeremy Gramps (bottom left), t o'brian (bottom right)*

Plants from the Solanaceae Family (tomatoes and eggplants), and many Australian native plants, including *Hibbertia* and *Dianella* species, are buzz pollinated. These plants have the capacity to support populations of native bees, but their pollen may not be as available to beneficial predators.

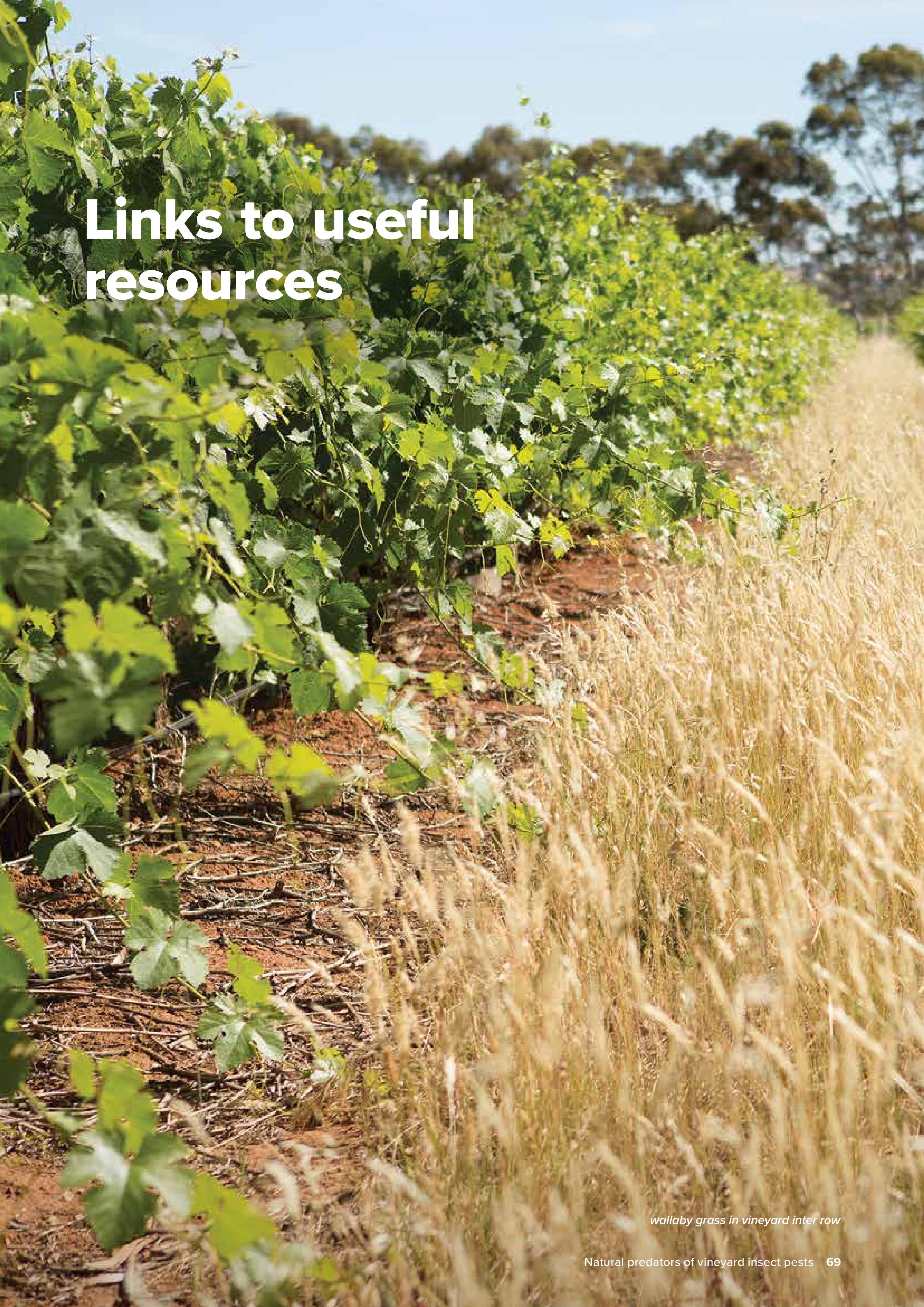
Significance to viticulture: grapevine flowers contain both male and female flower parts, and are self-pollinating – and so do not rely on insects to influence the pollination stage. Bees, nonetheless, enhance biodiversity in viticultural areas – especially by providing pollination services to insectary plant species. They also provide a source of alternative prey for predatory arthropods.

Sensitivity to sprays: bees are sensitive to organophosphates, sulfoxaflor, clothianidin, methidathion, fipronil, indoxacarb, spinosad, emamectin, methomyl, carbaryl and pyrethroids (CRDC 2019).

Amazing fact:

The creation of 'bee hotels' (see Figure 81) can encourage the presence of native bees, including the 'carpenter bee', 'leafcutter bee' and 'blue-banded bee'.

Links to useful resources



wallaby grass in vineyard inter row

6. Links to useful resources

Apps

'Spidentify' app and website **https://identify-spiders.com**

Websites

Agrochemicals registered for use in Australian viticulture **https://www.awri.com.au/industry_support/viticulture/agrochemicals/agrochemical_booklet**

Arachne.org.au – a digital field guide to help with spider identification **http://www.arachne.org.au/default.asp**

Atlas of Living Australia **https://bie.ala.org.au**

Australian Biological Control **http://www.goodbugs.org.au**

Australian dragonfly identification key **http://photos.rnr.id.au/dragonflies%20old.html**

Australian Museum **https://australianmuseum.net.au**

Aussie Bee **https://www.aussiebee.com.au**

Biological Services **http://biologicalservices.com.au**

Bugs for Bugs **https://bugsforbugs.com.au**

Butterflies, moths and beetles of Australia **https://sites.google.com/site/beetlesofaustralia/home**

Eye patterns of some Australian Araneomorphs (spiders) **http://www.arachne.org.au/_dbase_upl/araneomorpheyes.pdf**

Identification guide to the Australian Odonata (dragonflies and damselflies)) **https://www.environment.nsw.gov.au/resources/publications/09730austodonata.pdf**

Ladybirds of Australia **http://www.ento.csiro.au/biology/ladybirds/ladybirds.htm**

SA Natureteers (Facebook group) **https://www.facebook.com/groups/553438594757416**

What bug is that? – a guide to insect families **http://anic.ento.csiro.au/insectfamilies**

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Retallack MJ (2019) The functional diversity of predator arthropods in vineyards, *The Australian and New Zealand Grapegrower and Winemaker*, January **660**, 23–26 **https://winetitles.com.au/gwm/articles/january-660/the-functional-diversity-of-predator-arthropods-in-vineyards**

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Glossary

7. Glossary

Abdomen: one of the three main body segments of insects, and also one of the two main body parts of spiders and mites (usually known as the opisthosoma). It is the posterior body segment. Most arthropods have three body segments: the head, the thorax and the abdomen. Spiders and mites have a fused head and thorax (known as a cephalothorax or prosoma). In mites the cephalothorax and the opisthosoma (or abdomen) are also fused.

Arthropod: an invertebrate with an external skeleton, segmented body, and paired, jointed appendages. In this guide we refer to insects (flies, bugs, beetles, wasps, ants, lacewings, earwigs, mantises and katydids), and arachnids (spiders, mites and false scorpions).

Ballooning: a process where some species of spiders move through the air by releasing silken threads, which catch the wind and propel the spider airborne, to disperse or move between objects to construct a web.

Beneficial predatory arthropods: arthropods that predate on or parasitise other organisms that are considered pests. Analogous to the term 'natural enemy'.

Biodiversity: the diversity and richness of species.

Cerci: (singular 'cercus') are paired appendages on the rear segment of many arthropods.

Coleoptera: an Order of insects that refers to beetles. Beetles undergo complete metamorphosis and have chewing mouthparts.

Diurnal: predominantly active during the day.

Dorsal: the upper side of the body.

Ecosystem: a biological community of interacting organisms together with their physical environment.

Ecosystem services: the range of benefits that humans freely derive from well-functioning ecosystems and the natural environment.

Elytra: the hardened forewing of certain insect Orders, notably beetles and a few true bugs.

Functional biodiversity: also known as functional diversity – is the component of biodiversity concerning the range of things or functions that organisms do (or can do) within ecosystems.

Halteres: club-shaped, balancing organs located behind the forewings of a fly.

Hemiptera: an Order of insects that refers to 'true bugs', which all share a common arrangement of piercing and sucking mouthparts.

Honeydew: a sugar-rich liquid, secreted by aphids and some scale insects as they feed on plant sap.

Infraorder: a taxonomic category in biological classification ranking above a Superfamily and below a Suborder (see 'Taxonomic hierarchy' below).

Integrated pest management (IPM): an integrated pest management framework comprises the use of biological, cultural and chemical control options to manage economically damaging pests.

Insects: these are identified by the presence of three body parts (head, thorax and abdomen), three pairs of jointed legs, compound eyes, and one pair of antennae. Adults have two pairs of wings attached to the body at the thorax, which may be modified or absent.

Invertebrate: animals that do not have a backbone.

Insectary plants: are plants that attract beneficial arthropods, including insects. Insectary plants are typically intentionally introduced into an ecosystem to increase the pollen, nectar and habitat resources required by the beneficial predatory arthropods that can help control the insect pests of agricultural crops. Insectary plants also add to local biodiversity and environmental values.

Instar: a developmental phase between two periods of moulting in the development of an insect larva.

Larva: a distinct juvenile growth-stage form, prior to the process of metamorphosis: larva (singular), larvae (plural).

Light brown apple moth (LBAM): light brown apple moth, *Epiphyas postvittana*, is the main Lepidopteran pest of grapevines.

Mandibles: jaw-like mouthparts, which are used for chewing or crushing prey.

Metamorphosis: the change in body form and habits during the development cycle. 'Complete' metamorphosis consists of four growth stages: egg, larva, pupa and adult. 'Incomplete' metamorphosis consists of three growth stages: egg, nymph and adult.

Mimicry: is the resemblance between an organism and another object (typically an organism of another species).

Morphospecies: a group of organisms recognised as a taxonomic species based solely on shared morphological (form, shape and structure) features.

Moult: the shedding of part of an insect's body, either at specific times of the year or points in its lifecycle.

Natural enemy: arthropods that predate on or parasitise other organisms that are considered pests. Analogous to the term 'beneficial predatory arthropods'.

Nocturnal: predominantly active during the night.

Nymph: the immature form of insects, which undergoes metamorphosis before reaching the adult stage.

Omnivorous: feeds on both animal and plant matter.

Order: a taxonomic category within the classification hierarchy of arthropod species, at a higher level of classification than Family, Genus and species (see 'Taxonomic hierarchy' below).

Ovipositor: a tubular organ through which a female insect deposits eggs.

Parasitic: describing the process where one organism (the parasite) lives on or in another organism (the host).

Parasitoid: an organism that has young that develop on or within another organism (the host), eventually killing it – parasitoids have characteristics of both predators and parasites.

Pollinator: an insect that moves pollen from the male anther of a flower to the female stigma of a flower.

Predation: a biological interaction where one organism (predator), kills and eats another organism (prey).

Proboscis: a tubular piercing and sucking mouthpart of true bugs (Hemiptera): sometimes called a rostrum.

Pronotum: a prominent plate-like structure that covers all or part of the thorax of some insects.

Pupa: the transformation stage between immature and mature developmental stages (proceeding adulthood) of insects.

Resilience: the resilience of a natural system is defined by its capacity after disturbance (or in response to environmental change) to return to its initial state or to withstand the disturbance in the first place.

Rostrum: see 'proboscis'.

Scale insects: small insects of the Order Hemiptera. Adult females typically have soft bodies and no limbs, and are concealed underneath domed scales, extruding wax for protection. Males – when they occur – have legs and sometimes wings, and resemble small flies.

Spinnerets: a silk-spinning organ of the spider or the larva of an insect, usually located on the underside of the abdomen towards the rear.

Taxonomic hierarchy: arthropods (Arthropoda) are a Phylum within the taxonomic classification hierarchy of animal species; while insects (Insecta) are a Class.

The taxonomic hierarchy of arthropods and other animals in taxonomic arrangement comprises Domain, Kingdom, Phylum, Class, Order, Suborder, Family, Genus and species (there can also be Infraorders, Superfamilies, Subclasses, subspecies, etc).

The usual binomial name given to a species comprises the Genus and species names (e.g. *Micromus tasmaniae* is the scientific name for the brown lacewing).

Thorax: the middle section of an insect's body between the head and abdomen, bearing the legs and wings.

Thrips: (singular and plural 'thrips') small and slender insects of the Order Thysanoptera, with fringed wings and unique asymmetrical mouthparts.

Trophic level: the position an organism occupies within a food web.

Ventral: the underside of the body.

Veraison: the onset of ripening and change of colour of grapes.

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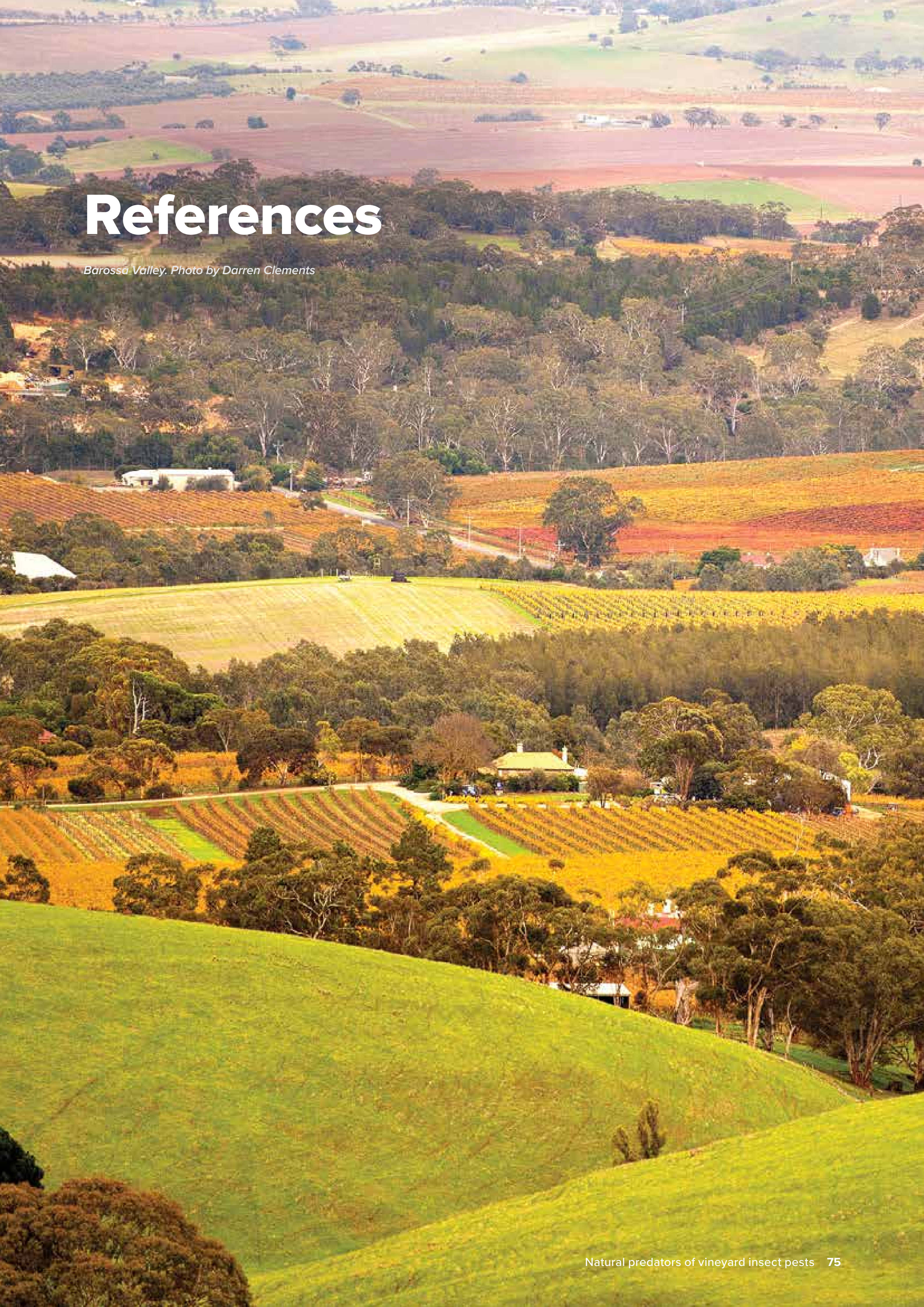

Barossa Valley. Photo by Darren Clements

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Blue-banded bees. Photo by Greg Coote

“Insectary plants provide food, shelter and alternative prey or hosts, which nourish and support the presence of beneficial predatory arthropods. In turn, predator arthropods provide ‘regulating’ ecosystem services, which involve biological suppression of vineyard pests.

Stands of native vegetation adjacent to vineyards have been associated with increased biodiversity and provide season-long benefits to boost the activity of beneficial predators and parasitoids.”

Dr Mary Retallack

Figure 82: A hoverfly foraging on the South Australian native plant, ‘twining fringe lily’, Thysanotus patersonii. *Image: Martin Stokes*

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Cover photo: green lacewing, Mallada signata *(Jeremy Gramp)*

Disclaimer

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