Spoon-winged lacewings are astonishing and mysterious visitors to flowers such as this cone flower (genus *Conostylis*) in southwestern Australia. These lacewings from the family Nemopteridae are known to be specialised pollinators in South Africa and the Mediterranean, but little is known about the Australian species, of which about 10 are known, in 4 genera. *Photo: Beth Kinsey*

# Beyond the birds and the bees

Ecologist **Manu Saunders** showcases some unusual plant-pollinator relationships.

Mention pollinators, and most people think of bees. Few animals are as popular across so many cultures as the European honey bee. Australians are also likely to visualise honeyeaters feasting on nectar in a flowering gum. But many others besides bees and birds offer floral services – flies, wasps, moths, ants, thrips, beetles and bats among them. Some plants rely on multiple types of pollinators, while others get by without bees or birds at all. The fig-wasp mutualism and the hormone-fuelled relationships between some orchids and wasps are well known examples of this. In Australia, where around 80% of flora and fauna are endemic, unusual plant-pollinator relationships are more commonplace than we might think.

Until quite recently, the scientific focus was on pollination 'syndromes', based on the assumption that particular features of flowers evolved to suit particular pollinators. For example, it was thought that red flowers are bird-pollinated and that bees like blue or yellow flowers with lots of pollen or nectar. Such generalisations hold in some cases, but as we discover more about the fascinating world of flowers, the exceptions have accumulated and the predictive value of these syndromes has declined.

## MARSUPIAL FLOWER VISITORS

**The honey possum is one of Australia's most unusual marsupials, specialised for a diet of nectar and pollen, with a long, brushtipped tongue, little in the way of teeth, a long snout and the highest basal metabolic rate of any marsupial. This could be due to its diet of easily digestible, high-energy food, or the high energy needed to visit sufficient plants to meet its daily energy requirements. Another unusual feature is that the males have the largest known sperm of any mammal. Honey possums are not regarded as threatened but have lost much habitat since European colonisation and may lose much more as the *Phytophthora cinnamomi* pathogen spreads. A large proportion of their food plants are susceptible to this devastating disease. *Photo: Chris Sanderson***

Many of Australia's marsupials visit flowers and are likely to be important pollinators, but far less is known about their services to flowers than is known about insects, birds or bats. The most highly adapted is the honey possum (*Tarsipes rostratus*), the only living member of family Tarsipedidae and the only non-flying mammal known to feed solely on nectar and pollen. A small group of bats are the only other mammals to do so.

Tiny and mouse-like, it has a long snout for flower probing and a long tongue for nectar drinking. It needs a year-round supply of flowers and keeps to heathy woodlands in the southwestern Australian biodiversity hotspot, typically where Proteaceae plants are abundant. It is thought to be a key pollinator of *Banksia* and *Adenanthos* species, as well as plants in the Myrtaceae family.

Some gliders, including the sugar glider and pygmy glider, also frequent flowers and can carry pollen on their furry bodies. Their acrobatics can carry them long distances between trees, contributing to the dispersal of pollen.

Many dasyurids eat pollen, nectar and floral parts, but although they are widespread and common across Australia they are rarely considered as pollinators. Some destroy flowers, but species from at least three genera, *Antechinus*, *Parantechinus* and *Sminthopsis*, are considered likely pollinators, based on their behaviour and studies of pollen carried on their snout and head. It's now accepted that non-flying mammals can pollinate many Australian plants, but much of the evidence is anecdotal, so there are plenty of questions to answer.

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## BREAKING-BUD POLLINATION

Can a flower be pollinated before it is fully open? Japanese researchers recently discovered a new mode of pollination in *Lycoris sanguinea*, a lily native to the east Asian coast and islands. Tiny halictid bees (*Lasioglossum* species) are just the right size to enter the slit at the top of the tubular-shaped bud as it starts to open. Once inside they move around collecting pollen, pollinating the flower in the process. If these bees visit the flower once it is fully open they do not help the plant, for the stigma (the female flower part) and anthers (the male pollen-carrying parts) are too far apart.

It's possible that this also occurs in other large, bisexual flowers. In Australia, many eucalypts (*Eucalyptus*, *Corymbia* and *Angophora* species) have flower structures that could support breaking-bud pollination by small bees. In some fully opened large blossoms the female stigma rises high above the pollen-topped stamens arranged around the edge. Birds, bats and some large bees and wasps are considered the main pollinators of eucalypts, because their large bodies make contact with male and female flower parts. Small native bees will often partake of the pollen and copious nectar without touching the stigma.

Despite a lot of research into eucalypts, especially economically important species, little is known about insect visitation and pollination under natural conditions. However, tiny native bees (*Hylaeus* and *Lasioglossum* species) can often be seen crowding into the breaking *Corymbia* bud before it is fully open. At this stage, the pollen-laden stamens the bees are seeking are curved into the centre of the flower cup, sitting adjacent to the stigma. As the bees move in and out collecting pollen, they have a good chance of brushing against the stigma, thereby pollinating the blossom before it opens.

This is an exciting new concept for pollination ecology. Few people would have thought a flower could be pollinated before it opened. It's clear we know a lot less about how nature works than we might think. ▸

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**When they open, these *Corymbia ficifolia* blossoms are regarded as typical of bird-pollinated flowers in their colour and structure (with the stigma too far above the stamens for small bees to brush against). But perhaps these *Hylaeus* bees in the closed blossom are doing some early pollinating. Breaking-bud pollination, as it is known, has only just been described, and not yet for any Australian species. *Photo: Manu Saunders***

## AN ANCIENT RELATIONSHIP

Cycads were around before the dinosaurs, and these palm-like trees haven't changed much since the Mesozoic. Because they lack flowers, cycads were traditionally assumed to be wind-pollinated like their non-flowering cousins, the conifers, gingkos and gnetales. But recent research has revealed that cycads, uniquely for gymnosperms, are serviced by insects. Some of them emit heat and volatiles to achieve this.

Specialised insect pollination has been proven for a number of cycad species, and is now thought to be the case for most of the group. Beetles, usually weevils, are the most common pollinators. However, some species in the Australian genus *Macrozamia* depend on thrips.

Most of the 40 odd *Macrozamia* species occur along Australia's east coast. A few are found in the southwest corner and one, *Macrozamia macdonnellii*, in central Australia. Unlike most non-Australian cycads, many *Macrozamia* species, including M. *macdonnelli*, are pollinated by either thrips only or by both thrips and weevils. These thrips species were identified as new to science, and the genus was called *Cycadothrips* after the plants they rely on for food and shelter.

## WEEVIL-PLANT SYNCHRONY

Weevils are thought to be among the earliest pollinators, for they attend other ancient plant groups besides cycads. One is Eupomatiaceae, which includes just three species, endemic to tropical and subtropical forests in Australia and New Guinea. Some of their floral characters fit those thought to be common in the first flowering plants, so their relationship with weevils (in genus *Elleschodes*) is probably old.

The most widespread of the three, the subtropical native guava (*Eupomatia laurina*), has white, waxy flowers made up of whorls of stamens and staminodes, and lacking petals and sepals. The flowers open in a female (receptive) phase, and change to male phase (with pollen exposed) by the evening, before dropping off the plant during the night. This flower phenology is in marvellous synchrony with the life cycle of its *Elleschodes* pollinators.

The fruity scented flowers seem to attract weevils and little else. They provide a safe haven by day for the weevils to feed, mate and lay their eggs. As the male phase flowers drop at day's end, the weevils leave, dusted with pollen, and at dawn they find a newly opened flower in female phase. Within two days of the flowers dropping to the forest floor the weevil larvae hatch and feed on the spent flower parts, before burrowing into the soil to pupate.

Little is known about the lifecycle of *Elleschodes* weevils. The best studied weevil pollination systems are in economically important plants like some date and oil palm species. But many other tropical and subtropical plants also rely on weevils to set seeds.

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**Native guava flowers produce potent fragrances irresistible to weevils from genus *Elleschodes*, whose lives revolve around these flowers for food, mating and egg laying. *Photo: Lui Weber***

A fascinating push-pull mechanism underlies this relationship. Thrips spend most of their time in male cycad cones, feeding on pollen and mating. At certain times of the day, these cones heat up and emit strong odours that drive the thrips out. Female cones then emit an attractive odour, enticing thrips in through tiny cracks.

This relationship shows that the evolutionary connection between flowers and insects is ancient. It gives more weight to recent fossil discoveries suggesting that thrips are the oldest known pollinators.

Thrips are also commonly found in angiosperm flowers feeding on nectar and pollen, and have recently been revealed as key pollinators for many plants. Their role is often overlooked because of their reputation as pests in orchards and gardens.

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**Cycads are unusual for gymnosperms in having insect pollinators – weevils or thrips or both. Shining burrawang (*Lepidozamia peroffskyana*, left), from eastern Australia, relies on a weevil in genus *Tranes* and *Macrozamia lucida* (right), also from eastern Australia, relies on the thrips *Cycadothrips chadwicki*, shown here leaving a male cone *Photos: Nick Fisher (left), Irene Terry (right)***

**While dining on nectar this southern snow skink performs an essential service for honey richeas by biting off their flower caps, thereby providing access for insect pollinators. *Photo: Tim Rudman***

## REPTILIAN HIRED HELP

Island life is often different. The isolation gives rise not only to unique species and communities but also to unique interactions. Lizards are rarely seen at flowers on the mainland, but are known pollinators on some islands, probably because islands have fewer pollinators, and fewer insects for lizards to eat. Pollinating lizards are known in New Zealand, and on islands in the Mediterranean Sea and Indian Ocean. At least one lizard-flower relationship is known in Australia – from Tasmania's high country.

The southern snow skink (*Niveoscincus microlepidotus*) keeps to alpine boulder fields and low heath above 1000 metres . It has an unusual reproductive cycle for a lizard, giving birth every second spring. And it plays an unusual role in the reproductive cycle of another Tasmanian endemic – the spectacular honey richea (*Richea scoparia*).

This plant is dressed for the harsh alpine climate, with very sharp, narrow leaves that are regularly cursed by bushwalkers. Its flowers come in various shades of white, yellow, red and pink, arranged in clusters on a spike. The petals are fused into a hard calyptrum that protects the delicate flower parts inside from alpine extremes. This is where the skink comes in.

The flowers fill up with sweet nectar when they are ready for pollination in spring, but the fused petals can't unfurl on their own. Instead, they rely on snow skinks in search of nectar to bite the cap off. The skinks don't transport pollen themselves, but by opening the flower they allow insects to fly in and finish the job.

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This female nartee (*Kawanaphila nartee*) has just mated and is bending to eat the gooey nuptial gift deposited by the male. The gift, called a spermatophylax, is attached to the sperm-containing part of the spermatophore that injects sperm into her as she eats the gift. She is on the unopened flower head of a kangaroo paw in Kings Park, Perth. *Photo: Darryl Gwynne*

## WHAT KATYDID

Katydids are often mistaken for grasshoppers, although they are closer to crickets and wetas. Most are herbivores or carnivores, and some are considered pests. One group of endemic Australian katydids, the 17 species of Zaprochilinae, are highly unusual as they feed almost entirely on pollen and nectar, the only katydids known to do so. They have specialised mouthparts for eating pollen and nectar without destroying the flower parts. Some crickets visit flowers, but flower-feeding is rare for other orthopterans.

There has been some speculation on the potential role of Zaprochilinae katydids as pollinators. Those from genus *Kawanaphila* seem likely contenders, for they are covered in fine hairs that would be suitable for transporting pollen. The 11 named species live in heath habitats in southwestern and southern Australia. The many different flowers they visit include those of *Acacia*, *Jacksonia*, *Angophora*, *Grevillea*, *Sterlingia*, *Anigozanthos* and *Xanthorrhoea* species.

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## MYSTERIOUS SAWFLIES

Sawflies are one of our most underappreciated pollinators. Because adults live only a few days in late summer and autumn, most people know sawflies only as the mounds of crystallised-looking larvae that congregate on eucalypt leaves and sometimes defoliate entire trees. They are major pests in eucalypt plantations, and reputed 'spitfires'. If threatened, they can regurgitate a eucalyptus oil-based fluid that can irritate eyes and skin, but their alleged spitting is an urban legend.

The short-lived adults feed mostly on nectar and pollen, like their closest relatives, the wasps. Male paperbark sawflies (*Lophyrotoma* species) are the main pollinators of the flying duck orchid (*Caleana major*), as they confuse the flowers for female sawflies. Sawfly adults have been observed on several other species, including *Boronia*, *Wahlenbergia* and *Eremophila* flowers, but little is known about the pollination role of these mysterious insects. ■

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Sawflies may turn out to be more important pollinators than realised. Male paperbark sawflies are well known for pollinating the flying duck orchid by being fooled into perceiving it as a mate, but whether sawflies are also important in pollinating other plants is not known. *Photo: Iris Curran*