# Beneficial Arthropods and Pathogens

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Conservation biological control seeks to preserve and enhance populations of resident beneficial organisms in cropping systems. When a crop environment is "friendly" to beneficial arthropods, biological control provided by endemic populations of predators and parasitoids can contribute substantially to pest management. In hop, beneficial arthropods can often provide partial and, in rare instances, complete control of spider mites and aphids, depending on the population densities of pest and prey, environmental conditions, and grower cultural practices.

The foundations of reliable conservation biological control include:
1) proper identification of beneficial organisms;
2) preservation of beneficial arthropods through use of selective pesticides that have low toxicity to beneficial insects and mites (see Table 1, page 7);
3) modification of cultural practices to provide refuge and extra-floral nectar and pollen resources for beneficial organisms (e.g., border plantings, hedgerows, ground covers).

A generalized summary of the seasonal development and activity of several key beneficial (predatory) arthropod groups is illustrated in Figure 131, below.

***At a Glance***

**Beneficial Arthropods**

- Learn to ID beneficial arthropods in the hop yard.
- Preserve them through use of selective pesticides.
- Conserve when possible.

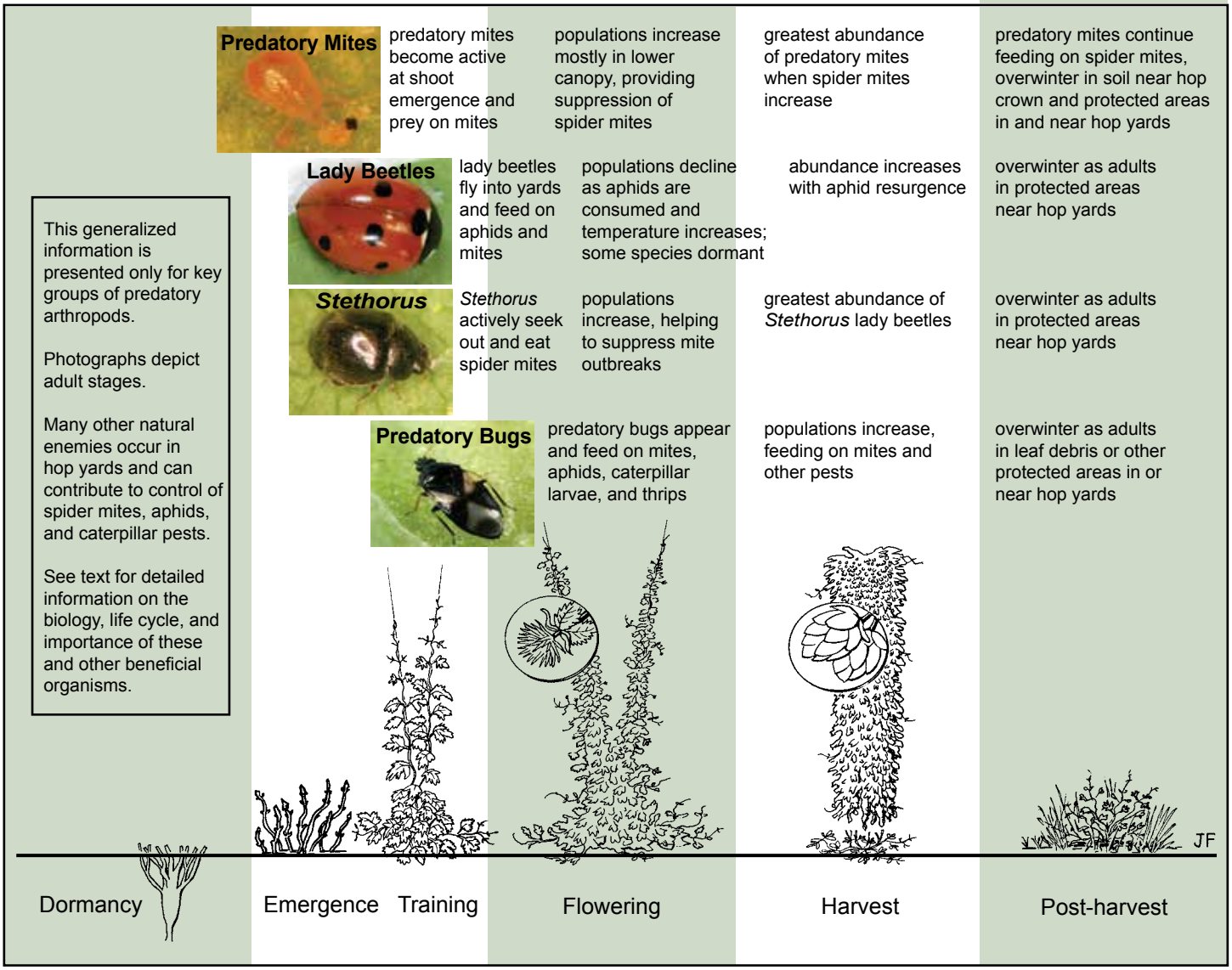



Figure 131. Seasonal development and activity of four key groups of predatory arthropods that occur on hop: predatory mites, aphid-eating lady beetles, mite-eating *(Stethorus)* lady beetles, and predatory bugs. Information is generalized; multiple factors influence the presence and abundance of beneficial arthropods in hop yards. Detailed sections for each of these predator groups and for other beneficial arthropods appear on the following pages. (Illustrations by Joel Floyd)

***At a Glance***

**Predatory Mites**

- Predatory mites are important biocontrol agents of spider mites.
- Some predatory mites feed on aphids and on hop looper eggs.
- Always monitor for predatory mites as well as spider mites.
- Predatory mites move faster than pest mites.
- Adults can eat three to 10 spider mites and/or eggs a day.
- Consider population density of predatory mites (1 predator to 20 pests) before applying miticides.
- Always use miticides and insecticides that are nontoxic or partially toxic to predatory mites.

## Predatory Mites

A number of predatory mites occur on hop. In the Pacific Northwest, these include the phytoseiids *Galendromus occidentalis* (western predatory mite), *Amblyseius fallacis*, and *Neoseiulus fallacis,* and the anystid, *Anystis* spp. (whirligig mite). All feed on spider mites, and *Anystis* spp. also feed on aphids and on hop looper eggs. *Galendromus occidentalis* and *N. fallacis* are generally pale tan-colored, pear-shaped, shiny, and more active than spider mites (Figs. 132-135). *A. fallacis* adults, also pear-shaped, start out white and turn brownish-red after feeding. *A. fallacis* tend to die out after abamectin is sprayed in the hop yard.

Predatory mites move faster than pest mites. They range in size from 1/50 to 1/25 inch in length and have needle-like mouthparts, which they use to puncture spider mites and suck out body contents. Predatory mites feeding on spider mites change color, temporarily reflecting their meal. Eggs of phytoseiid mites are oblong and slightly larger than the spherical eggs of spider mites (Figs. 132 and 135). Nymphs are smaller and lighter in color, but otherwise are miniature versions of the adult. Anystid mites are velvety red and up to 1/10 inch long (Fig. 136).

Figure 132. Adult predatory mite, *Galendromus occidentalis*, lower right, with its opaque, oblong egg. Above left is a twospotted spider mite adult. Most predatory mites range in size from 1/50 to 1/25 inch in length. (D.G. James)

Figure 133. Adult predatory mite, *Neoseiulus fallacis*. Notice shiny appearance and distinctive pear shape. (D.G. James)

Figure 134. *Neoseiulus fallacis* are shinier and faster than *G. occidentalis* and are able to feed on pollen as well as on spider mites. They flourish under cool, moist conditions such as those found in western Oregon. (D.G. James)

## Biology and Life History

Predatory mites (Phytoseiids) pass through four stages before becoming adults: egg, larva, protonymph, and deutonymph. Eggs generally require high humidity for survival and hatching, a condition provided by the hop leaf surface. Larvae and nymphs are active predators, consuming spider mite eggs and motiles. Phytoseiids develop faster than spider mites, with *G. occidentalis* and *N. fallacis* completing development within a week during the summer. Mating is required for reproduction, and females (66 to 75% of the population) lay one to five eggs per day for up to six weeks. Adults can eat three to 10 spider mites and/or eggs a day, depending on temperature. Up to 12 generations of predatory mites may occur on hop during the growing season, and very large populations can develop by mid-summer.

Most hop yards in Washington State have both *G. occidentalis* and *N. fallacis* present in proportions that vary with location and year. *Galendromus occidentalis* is better adapted to hot, dry conditions, while *N. fallacis* flourishes under cool, moist conditions, thus dominating the phytoseiid fauna in Oregon hop yards. *Neoseiulus fallacis* is shinier and faster than *G. occidentalis* and is able to feed on pollen as well as on spider mites, enabling persistence in hop yards even when spider mite numbers are low. Mature females of both species overwinter in hop yard leaf litter, debris, soil, or pole fissures. Activity resumes in March to April when spider mites colonize new hop growth.

Less is known about the biology of *Anystis* mites, which are becoming more frequent in hop yards as pesticide inputs lessen. They are active predators of hop aphid and, to a lesser extent, mites and small insects like thrips. They are very rapid movers and are long-lived as adults. Development from egg to adult takes more than a month, but adults eat large numbers of mites, up to 40 per day. Two generations occur per year. *Anystis* mites' biology complements the rapid developmental biology of phytoseiids and it is expected that they will become an important component of IPM as use of broad-spectrum pesticides continues to decrease.

## Predatory Mites

### Monitoring, Importance in IPM, and Compatibility with Pesticides

Predatory mites are readily monitored by sampling and examining leaves with a hand lens or microscope. Their rapid movement easily distinguishes them from slower-moving spider mites.

A definitive guide to determining the number of predatory mites needed to give good biological control of spider mites on hop has not been developed. It is common to find predatory mites actively feeding on spider mites in hop yards after shoot emergence in early spring. Later in spring, however, populations of predatory mites in hop yards generally are too small (fewer than one per leaf) to control a rapidly expanding mite population. However, by July predatory mite numbers are often large enough (one to five per leaf) to provide control of spider mites. A predator:prey ratio of 1:20 or lower often will result in acceptable biological control.

Although predatory mites, particularly *Galendromus occidentalis* and *Neoseiulus fallacis*, are very important in the biological control of spider mites during July and August, acceptable biological control only occurs when insect predators of spider mites, such as mite-feeding lady beetles, also are present.

Predatory mites are extremely sensitive to broad-spectrum pesticides and sulfur fungicides. However, many new-generation insecticides, miticides, and fungicides are non-toxic to predatory mites and should be used in preference to those that are not. Predatory mites also can be conserved by providing in-yard and adjacent refugia that harbor overwintering populations.

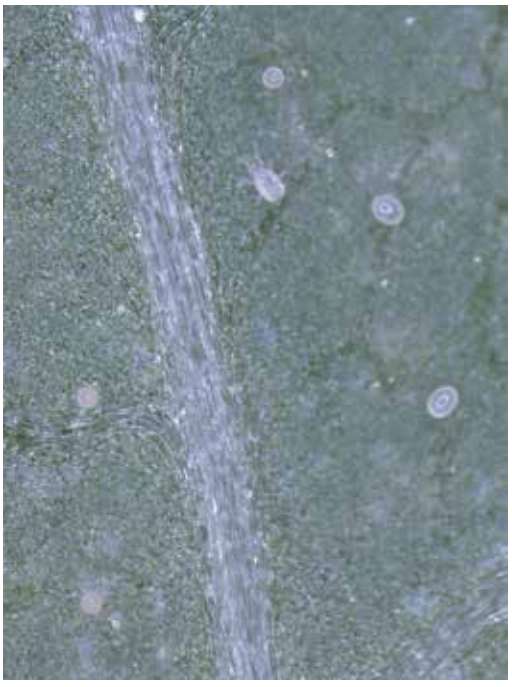


Figure 135. *Galendromus occidentalis* immature and two (oval) eggs. The round eggs at the top and left are pest mite eggs. (T. Brooks)

Figure 136. An anystid mite, *Anystis* spp. These are larger than other beneficial mites. (A.J. Dreves)

***At a Glance***

**Aphid-Feeding Lady Beetles**

- Lady beetle adults and larvae help control aphids, spider mites, and other small insects.
- Monitor for aphid-feeding lady beetles; one adult every second or third plant can help suppress aphids.
- Always use lady beetle-compatible insecticides to control aphids.

# Predatory Lady Beetles

Hop yards are readily colonized by several species of lady beetles (Coccinellidae), which play a major role in suppressing aphid and, to a lesser extent, spider mite populations. Four species of primarily aphid-feeding lady beetles and two species of mite-feeding lady beetles are most frequently seen and are discussed separately.

## Aphid Feeders

### Transverse Lady Beetle
*Coccinella transversoguttata*

#### Description

The adult is approximately ¼ inch long and rounded. The wing covers (elytra) are orange with distinct, narrow transverse black markings (Fig. 137). The body and pronotum (area between the head and wing cases) are black with small white or yellow patches. The yellowish-orange, spindle-shaped eggs are laid in batches. The alligator-shaped larva is purple-blue with orange markings.

#### Biology and Life History

Transverse lady beetles are native to North America but declining in abundance throughout much of Canada and the eastern U.S. However, they are still relatively common in eastern Washington and are frequently found in hop yards. Overwintered beetles fly into hop yards during April and May and feed on newly established colonies of hop aphids. In some years, *C. transversoguttata* is very common, but in others it can be scarce; the cause of these population fluctuations is unknown. Transverse lady beetles are also found in other aphid-affected crops such as tree fruit. Adults may consume up to 100 aphids a day depending on temperature. Larvae are also voracious feeders. When prey is scarce, adults can survive (but not reproduce) on nectar, honeydew, and pollen. Larvae molt through four instars before pupating. The life cycle from egg to adult takes approximately three weeks during summer.

Figure 137. Adult stage of the transverse lady beetle is approximately ¼ inch long and rounded with distinct narrow black markings on the wing covers. (D.G. James)

### Convergent Lady Beetle
*Hippodamia convergens*

#### Description

The adult is approximately 1/4 inch in length and more oval than round (Fig. 138). The wing covers are orange to red, typically with 12 to 13 black spots. However, the number of spots is variable, and some individuals have none. The first section between the head and thorax (pronotum) is black with two converging white stripes and white edges. The small head is almost covered by the front of the thorax. Legs and antennae are short. The egg is approximately 1/20 inch, bright yellow, elongate, and pointed at one end. Eggs are laid in clusters. The alligator-shaped larva is dark gray to blackish-blue with two small, indistinct orange spots on the pronotum and four larger ones on the back (Fig. 139). The pupa is orange and black and often attached to the upper surface of a leaf.

#### Biology and Life History

Convergent lady beetles are native and common in hop yards. They also are available commercially. Females lay 200 to 500 eggs, which hatch in five to seven days. Development through larval and pupal stages takes three to six weeks depending on temperature and food availability, with one to two generations a season. The largest populations in hop yards occur during spring; convergent lady beetles tend to disappear when weather becomes hot. Field evidence suggests that populations migrate to cooler, high-elevation areas in summer and aestivate (enter summer dormancy). Congregations of millions of inactive convergent lady beetles may be found during July to August in the Blue Mountains of northeastern Oregon and southeastern Washington states (Fig. 140). Most of these beetles overwinter in the mountains before migrating back to valley areas in spring.

# Multicolored Asian Lady Beetle
*Harmonia axyridis*

## Description

Adults are strongly oval and convex, approximately ¼ inch long (Fig. 141). They are highly variable in color and pattern, but most commonly are orange to red with many to no black spots. Some individuals are black with several large, orange spots. The first section between the head and thorax is straw-yellow with up to five black spots or with lateral spots usually joined to form two curved lines, an M-shaped mark, or a solid trapezoid. Eggs are bright yellow and laid in clusters of approximately 20 on the undersides of leaves. Larvae are elongate, somewhat flattened, and adorned with strong round nodules (tubercles) and spines (Fig. 142). The mature larva (fourth instar) is strikingly colored: the overall color is black to dark bluish-gray, with a prominent bright yellow-orange patch on the sides of abdominal segments 1 to 5.

## Biology and Life History

This exotic species is considered to be primarily forest-dwelling, but it appears to be well-adapted to living in hop yards and is often the most common lady beetle species present.

Unmated females overwinter in large congregations, often in buildings or caves (Fig. 143). Mating occurs in spring, and eggs hatch in five to seven days. In summer, the larval stage is completed in 12 to 14 days, and the pupal stage requires an additional five to six days (Fig. 144). In cool conditions development may take up to 36 days. Adults may live for two to three years. *H. axyridis* is a voracious predator, feeding on scale insects, insect eggs, small caterpillars, and spider mites, as well as aphids. Adults consume 100 to 300 aphids a day, and up to 1,200 aphids may be consumed during larval development.

Figure 141. Adult *H. axyridis* vary in color. (D.G. James)

Figure 142. Fourth-instar *H. axyridis* larva. (D.G. James)

Figure 138. Convergent lady beetle adult. (R. Ottens, Bugwood.org)

Figure 139. Alligator-shaped convergent lady beetle larva has orange spots. (D.G. James)

Figure 143. Overwintering *H. axyridis*. (D.G. James)

Figure 140. Convergent lady beetle adults congregating during aestivation. (D.G. James)

Figure 144. This lady beetle pupa is likely that of *H. axyridis*. (E. Lizotte)

**A generalized summary of the seasonal development and activity of key predatory arthropods including lady beetles is illustrated in Figure 131, page 71.**

# Seven-Spot Lady Beetle
*Coccinella septempunctata*

## Description

This species is comparatively large (approximately 3/8 inch), with a white or pale spot on either side of the first section between the head and thorax (Fig. 145). The body is oval and domed. The spot pattern is usually 1-4-2, black on the orange or red wing cases. Eggs are spindle-shaped and small, approximately 1/25 inch long. Larvae are alligator-like, dark gray with orange spots on segments 1 and 4 (Fig. 146), and grow to the same length as adults before they pupate (Fig 147).

AT RIGHT: Figure 145. Adult seven-spot lady beetle. (D.G. James)

AT RIGHT, TOP: Figure 146. Alligator-like larva is dark gray with orange spots. (R. Otten, Bugwood.org)

AT RIGHT, BOTTOM: Figure 147. Pupal stage lasts 3 to 12 days. (D.G. James)

## Biology and Life History

This exotic species is a relative newcomer to hop yards, unknown before approximately 2000. Currently, it is well established and often as common and important as *H. axyridis* in controlling hop aphids. Adults overwinter in protected sites near fields where they fed and reproduced the previous season. In spring, emerging beetles feed on aphids before laying eggs. Females may lay 200 to 1,000 or more eggs during a period of one to three months, commencing in spring or early summer. The spindle-shaped eggs are usually deposited near prey, in small clusters of 10 to 50 in protected sites on leaves and stems. Larvae grow from 1/25 to 3/8 inch in 10 to 30 days depending on the supply of aphids. Older larvae may travel up to 36 feet in search of prey. The pupal stage lasts from three to 12 days depending on temperature. Adults are most abundant in mid- to late summer and live for weeks or months, depending on availability of prey and time of year. One to two generations occur before adults enter winter hibernation.

## Aphid-Feeding Lady Beetles
### Monitoring, Importance in IPM, and Compatibility with Pesticides

Aphid-eating lady beetles can be important to natural suppression of hop aphids in areas where high temperatures do not keep aphid populations below damaging levels. Growers should encourage the species described here to colonize and reside in hop yards. Attraction and conservation of lady beetles is more effective and sustainable than the purchase and introduction of *H. convergens*, which tend to rapidly disperse from hop yards after release. Despite feeding primarily on aphids, these lady beetles also can feed on spider mites, thrips, and other small insects, and thus contribute at some level to overall biological control. Lady beetles can be monitored by simply walking through yards and conducting timed counts. Alternatively, they can be sampled by shaking foliage over a tray. A mean of one adult lady beetle every second or third plant represents a significant population capable of responding to aphid population increases. Lady beetles are compatible with many new, selective insecticides and miticides but are negatively affected by older, broad-spectrum pesticides.

## Mite Feeders
# Mite-Eating Lady Beetles
*Stethorus picipes, S. punctillum*

## Description

Mite-eating lady beetles are black, tiny (1/25 to 1/16 inch), oval, convex, and shiny, covered with sparse, fine, yellowish-to-white hairs (Fig. 148). Emerging adults are reddish-orange for a few hours before turning black. The white, oval eggs are less than 1/50 inch long, and turn dark just before the larvae emerge (Fig. 149). Eggs are laid singly, usually on the underside of leaves near the primary vein, and adhere tightly to the leaf. The newly hatched larva is gray to blackish and has many long-branched hairs and black patches (Fig. 150). The larvae grow from 1/25 to 1/16 inch long, becoming reddish as they mature, at first on the edges of the body. The entire larva turns reddish just prior to pupation. The pupae are black, flattened, and somewhat pointed on the posterior end, with the entire body covered with yellow hairs (Fig. 150).

### Mite-Feeding Lady Beetles
### Monitoring, Importance in IPM, and Compatibility with Pesticides

Mite-eating lady beetles are critical to good biological control of spider mites. One or two Stethorus beetles are usually sufficient to control an early-season mite "hot spot," preventing it from spreading into a larger outbreak. In combination with predatory mites, Stethorus may maintain non-damaging levels of spider mites during July and August. Monitoring can be conducted by examining leaves in the field or a laboratory by looking for tiny alligator-like larvae or mobile, pinhead-sized black dots. The beetles also can be shaken from bines and collected onto a tray. *Stethorus* spp. are susceptible to broad-spectrum insecticides and miticides such as abamectin. However, many narrow-spectrum pesticides are compatible with the survival of these important predators.

TOP: Figure 148. Adult mite-eating lady beetles are 1/25 to 1/16 inch long.
MIDDLE: Figure 149. White, oval eggs are less than 1/50 inch long.
BOTTOM: Figure 150. Newly hatched *S. picipes* larva. (3 photos, D.G. James)

## Biology and Life History

*Stethorus picipes* (a native species) is most commonly found in hop yards, but *S. punctillum* (exotic) also occurs. Both species are found in hop yards not exposed to broad-spectrum pesticides and are voracious spider mite feeders, consuming 50 to 75 mites per day. Overwintering occurs as non-reproductive adults in protected habitats (e.g., in ground debris, under bark) away from hop yards. Adults emerge from hibernation sites in late March and April, and seek out spider mite colonies in hop yards, which they are able to do extraordinarily well. Once prey is found, female Stethorus feed and lay eggs (approximately 15 eggs per day), rapidly exterminating small colonies of mites. Larvae develop through four instars, pupating after 12 days. Development from egg to adult takes approximately three weeks, and three to four generations are produced during spring-summer. Adults live for four to eight weeks during summer and thrive at temperatures between 68 and 95°F.

### *At a Glance*
### Mite-Feeding Lady Beetles

- Monitor for mite-eating lady beetles.
- Learn to recognize "black dot" adults and alligator-type black larvae.
- These voracious spider mite feeders consume 50 to 75 mites per day.
- Spider mite "hot spots" can be suppressed by 1 or 2 mite-eating lady beetles.
- Use only insecticides and miticides safe to mite-eating lady beetles.

Figure 151. Pupa of the mite-eating lady beetle *S. picipes* has pointed posterior end and yellow hairs covering the body. (D.G. James)

***At a Glance***
**Predatory Bugs**

- Recognize and identify predatory bugs.
- Predatory bugs are important in suppression of mites and aphids.
- Predatory bugs also feed on eggs, immature and adult thrips, loopers, and other soft-bodied arthropods.
- Monitor predatory bugs by shake sampling or direct counts on foliage.
- Always use insecticides and miticides safe to predatory bugs.

# Predatory Bugs

The predatory bugs described here are true bugs, belonging to the insect order Hemiptera. Predatory bugs have shield-like, thickened forewings and suck out the body contents of their prey through tubular, stylet-like mouthparts. All of the predatory bugs found on hop feed on more than one type of prey, consuming the eggs, immatures, and adults of a wide variety of prey including mites, aphids, caterpillars, and thrips.

## Minute Pirate Bug
*Orius tristicolor*

### Description

Adult minute pirate bugs are 1/12 to 1/5 inch long, oval, and black or purplish with white markings on the forewings (Fig. 152). The wings extend beyond the tip of the body. The tiny (1/100 inch) eggs are embedded in plant tissue with the "lid" exposed, through which the nymph emerges (Fig. 153). Newly hatched nymphs are transparent with a slight yellow tinge, turning yellow-orange to brown with maturity (Fig. 154). They are fast moving, wingless, and teardrop-shaped.

Figure 152. Adult minute pirate bug. (D.G. James)

Figure 153. First-instar nymph and egg of the minute pirate bug. Eggs are extremely small (1/100 inch) and embedded within leaves. (D.G. James)

### Biology and Life History

Minute pirate bugs overwinter as adults in leaf litter or under bark and usually emerge from hibernation in late March or early April. They feed on mites, aphids, thrips, hop loopers, and other soft-bodied insects. Eggs take three to five days to hatch, and development from egg to adult through five nymphal stages takes a minimum of 20 days. Females lay an average of approximately 130 eggs over a 35-day period, and several generations are produced during spring and summer. When prey is not available, minute pirate bugs are able to survive feeding on pollen and plant juices. Adults and immatures can consume 30 to 40 spider mites or aphids per day. Minute pirate bugs are efficient at locating prey and are voracious feeders. They aggregate in areas of high prey density and increase their numbers more rapidly when there is an abundance of prey. Minute pirate bugs are common predators in low-input hop yards and may contribute to control of late-season pests, particularly spider mites and hop loopers.

Figure 154. Minute pirate bug nymphs are wingless and teardrop-shaped. Older ones are yellow-orange to brown in color. (D.G. James)

## Big-Eyed Bug
*Geocoris pallens*

### Description

Big-eyed bugs play a beneficial role in Pacific Northwest hop yards. They are widely distributed across the western U.S. and range eastward to the Midwest. Oval, somewhat flattened, and 1/10 to 1/5 inch in length, they are usually gray-brown to blackish and have a wide head with prominent, bulging eyes (Fig. 155). Antennae are short and enlarged at the tip. Big-eyed bugs walk with a distinctive "waggle" and emit an unpleasant odor when handled. Eggs are cylindrical, ribbed, and pink or yellowish-white with a distinctive red spot. Eggs hatch into nymphs that resemble adults, except they are smaller and lack wings.

Figure 155. Adult big-eyed bug has prominent, bulging eyes. (D.G. James)

### Biology and Life History

Eggs are deposited singly or in clusters on leaves near potential prey and hatch in approximately a week. Development from egg to adult through five nymphal stages takes approximately 30 days under summer conditions. Both adults and nymphs are predatory, but can survive on nectar and honeydew when prey is scarce. Nymphs may consume up to 1,600 spider mites during development, and adults feed on 80 to 100 mites a day. Big-eyed bugs prey on a wide variety of insects and mites smaller than themselves. They feed on eggs and small larvae of hop loopers and other caterpillar pests, as well as all stages of thrips, aphids, and mites. Two to three generations a year occur between April and September. Adults overwinter in leaf litter or debris, or under bark.

## Predatory Mirid
*Deraeocoris brevis*

### Description

Adult predatory mirids *(Deraeocoris brevis)* are oval, shiny black with paler markings, 1/10 to 1/5 inch long, and approximately 1/12 inch wide (Fig. 156). Eggs are elongate, approximately 1/25 inch long, and inserted into plant tissue, often at the midrib of a leaf, with only the "lid" and a respiratory horn visible (Fig. 157). Nymphs are mottled pale gray with long gray hairs on the thorax and abdomen (Fig. 158). A cottony secretion covers most of the body. Dark areas on the thorax and abdomen give it a spotted appearance. The eyes are dull red.

Figure 156. Oval, shiny black adult predatory mirids. (D.G. James)

### Biology and Life History

*Deraeocoris* overwinters as an adult in protected places such as under bark or in leaf litter. Overwintered adults emerge from hibernation during March to April and feed on nectar of willow catkins and other early spring flowers. They seek out prey and begin laying eggs in late April or May. Nymphs of the first generation occur two to three weeks later. Nymphs develop through five stages in approximately 25 days at 70°F. Females lay up to 250 eggs during their lifetime, and adults consume 10 to 20 aphids or mites a day. Nymphs can eat 400 mite eggs a day. *Deraeocoris* adults and nymphs are important predators that prey on a wide variety of small insects and mites including aphids, thrips, leafhoppers, scale insects, small caterpillars, and spider mites. Two or three generations are produced between May and September. *Deraeocoris* is abundant in many agricultural and non-agricultural habitats in the Pacific Northwest.

Figure 157. Elongate predatory mirid eggs are inserted into plant tissue. (D.G. James)

AT LEFT: Figure 158. Predatory mirid nymphs are mottled pale gray with long gray hairs on the thorax and abdomen. (D.G. James)

## Monitoring, Importance in IPM, and Compatibility with Pesticides

Predatory bugs are an important component of IPM, providing control and suppression of spider mites, aphids, loopers, and thrips. In regions with warmer summers, predatory bugs are most important when aphid populations are present in late spring and early summer. In cool summer locations, predatory bugs are important for aphid control in late summer.

The abundance of predatory bugs in hop yards is likely to increase as broad-spectrum pesticide use decreases and greater use is made of ground covers.

Monitoring of predatory bugs is best done by visual scanning of foliage or by taking canopy shake samples.

# Assassin Bugs
Reduviidae

### Description

Adults are blackish, brown, or reddish with a long, narrow head. They have round, beady eyes and an extended, three-segmented, needle-like beak (Figs. 159 and 160). They are larger than other predatory bugs, ranging from 2/5 to 4/5 inch in length. Assassin bug eggs are reddish-brown, skittle-shaped, laid in a raft of 10 to 25 or more, and coated with a sticky substance for protection (Fig. 161). Nymphs are small versions of adults, although early instars are often ant-like.

### Biology and Life History

Assasin bugs are long-lived and consume large numbers of insects and mites during their lifetime. Adults may live for more than one season, and nymphs are slow to develop. Population densities of assassin bugs are usually low, but they provide useful, consistent, and long-term feeding on aphids and caterpillars in hop yards. They are most frequently found in yards with a ground cover.

# Damsel Bugs
*Nabis* spp.

### Description

Damsel bugs are mostly yellowish, gray, or dull brown, slender insects up to ½ inch long with an elongate head and long antennae (Figs. 162 and 163). The front legs are enlarged for grasping prey. Cylindrical white eggs are deposited on leaf surfaces near potential prey. Nymphs look like small adults but are wingless.

### Biology and Life History

Adult damsel bugs overwinter in ground cover, debris, and protected sites. They emerge from hibernation in April and soon begin laying eggs. Numerous overlapping generations occur during the season. Both adults and nymphs feed on soft-bodied insects and mites including aphids, loopers, spider mites, leafhoppers, small caterpillars, and thrips. A number of damsel bug species are seen in hop yards, particularly those with a ground cover.

Figures 159 and 160. Adult assassin bug feeding on a beetle larva. (D.G. James)

Figure 161. Raft of eggs laid by an assassin bug. (D.G. James)

Figures 162 and 163.
Adult damsel bug. (D.G. James)

# Parasitic Wasps (Parasitoids)

## Description

Parasitic insects that attack and kill other insects are termed parasitoids. Many species of wasp parasitoids attack eggs, larvae, or pupae of hop pests such as loopers, cutworms, leafrollers, and aphids. There are several families of parasitic wasps; some have a noticeable stinger/ovipositor specialized for piercing their hosts. Families are distinguished primarily by differences in wing venation. Adults are usually small, ranging from less than 1/12 to 1 inch long, with two pairs of membranous wings folded over their backs. They are black-brown to metallic blue in color and have medium to long segmented antennae. Some are slender with long bodies (Ichneumonidae, Figs. 164-166); others smaller (<1/3 inch) with fewer veins on wings (Braconidae and Trichogrammidae); and some are tiny (<1/5 inch) and stout with reduced wing venation (Chalcidae). The larvae of most wasp parasitoids are white, legless, and maggot-like. Some examples of wasp species found in hop yards include *Lysiphlebus testaceipes, Praon* spp., *Trichogramma* spp., *Bracon* spp., *Aphelenid* spp., *Aphidius* spp., and *Aphelinus* spp. Yellow jackets, hornets, paper wasps, and sand wasps will also attack and consume larger prey such as caterpillars.

### Parasitic Wasps
### Monitoring, Importance in IPM, and Compatibility with Pesticides

Parasitic wasps can be monitored by placing a light-colored tray or cloth directly under a bine and shaking the bine vigorously to dislodge pests and wasps out of the canopy and onto the tray. Close observation can reveal the tiny parasitoids. Yellow sticky traps may also be used to monitor wasp parasitoids. Wasp parasitoids are important in the biological control of hop looper and other caterpillar pests of hop. They also play a role in controlling hop aphid, but usually only on the overwintering *Prunus* spp. host of this pest.

## Biology and Life History

One to numerous generations of parasitoids can occur in a year, depending on species and temperature. A parasitic wasp's life history is closely synchronized with the presence of its host. Most wasp parasitoids overwinter as pupae or prepupae in soil, under debris, within the host, or in other protected areas in the hop yard. Female parasitoids lay eggs within the eggs, larvae, or pupae of hosts, and the wasp larvae develop on or within the host body as they consume the pest's organs and tissues. When the larva matures, it pupates then emerges from the prey's body as a wasp.

At least nine species of parasitoids are associated with the various life stages of the hop looper. Looper pupae are attacked by two ichneumonid wasps in Washington, *Pimpla sanguinipes* and *Vulgichneumon brevicinctor*. These species can be very abundant in hop yards after harvest and can help reduce the number of overwintering adult loopers. Two species of *Trichogramma* wasps attack looper eggs, with as many as three adult wasps emerging from a single egg. When not disrupted by pesticides, these minute wasps are capable of season-long parasitism rates of approximately 20%, with occasional peaks of up to 70%.

In addition to prey, extra-floral nectar and pollen produced by plants in and around hop yards are important water and nutrition sources for adult parasitoids. Survival and egg laying can be enhanced by providing these resources.

Figures 164, 165, and 166.
Various ichneumonid wasps. Adults are up to 1 inch in length. (D.G. James)

***At a Glance***
### Parasitic Wasps

- Wasps are important parasitoids of eggs, larvae, or pupae of hop loopers and other caterpillar pests.
- Encourage flowering ground covers that provide nectar for wasps.
- Use insecticides and miticides safe to wasps.

*At a Glance*

**Parasitic & Predatory Flies**

- Identify and monitor adult and larval predatory flies.
- Predatory flies feed on aphids, spider mites, thrips, and the eggs and adults of small insects.
- Use insecticides and miticides safe to predatory flies.
- Encourage flowering ground covers that provide nectar for predatory flies.

# Parasitic and Predatory Flies

A number of fly species from at least five families are known as predators or parasitoids of hop pests in the Pacific Northwest. They are presented in alphabetical order.

## Dance Flies

Adult dance flies (Fig. 167) are small- to medium-sized (< ¼ inch) and dark in color. They have a humpbacked thorax, a long, tapering abdomen, and slender legs. Dance flies are predators as adults and larvae, consuming smaller insects like aphids. Adults use their front legs to grasp small insects on the wing and pierce them with their sharp snout. The larvae are pale and cylindrical and live in the soil or decaying vegetation, preying on small insects and mites. Adults also visit flowers and swarm for mating. The larvae are generally found on moist terrestrial soil or rotten wood and are predacious on various arthropods.

Adult dance flies may be monitored using yellow sticky traps. Their value in hop yards is undetermined, but they may contribute to suppression of hop aphids.

Figure 167. Adult dance fly. (D.G. James)

Figure 168. Adult hover fly. (D.G. James)

Figure 169. Hover fly larva attacking a hop aphid. (D.G. James)

## Hover Flies

The yellow-and-black-banded adult hover fly resembles a stinging bee or wasp, but only has one pair of wings (Fig. 168). Hover flies lay single white, oblong eggs near aphid infestations. The adult is not predaceous but feeds on flower nectar. The larvae are approximately ¼ to ½ inch long, green to light brown, with a wrinkled-looking body that is blunt at the rear and pointed at the mouth end (Fig. 169). The pupae are pear-shaped and greenish to dark brown (Fig. 170). A number of species occur in hop yards and may be black-and-yellow or black-and-white banded.

Hover flies overwinter as pupae in the soil or above ground in leaves and plant material. The adult flies become active during spring (April and May), laying eggs on leaves and stems of hop plants harboring aphids. Hover flies are good fliers, disperse widely, and seek out aphid infestations very effectively. Larvae feed on aphids for approximately seven to 10 days and then pupate. The larvae are voracious feeders: as many as 300 to 400 aphids may be consumed by one larva during development.

Adult hover flies may be monitored using yellow sticky traps; the maggot-like larvae can be found amongst aphid colonies. Hover flies are an important component of biologically based hop aphid management. In combination with lady beetles and predatory bugs, they can provide rapid control of aphid infestations. Hover flies are generally sensitive to broad-spectrum pesticides.

Figure 170. Hover fly pupa. (D.G. James)

## Long-legged Flies

These small- to medium-sized (¼ to 3/8 inch), slender flies can be metallic-green, blue, or bronze in color; they have long legs, and large, prominent eyes (Fig. 171). The wings are clear with some darker markings, depending on species. The larva is maggot-like. Larvae and adults prey on small insects such as aphids, thrips, and spider mites.

Adult long-legged flies commonly sit on hop leaves and may be monitored using timed counts or yellow sticky traps. Their value in hop yards is undetermined, but they likely contribute to suppression of aphids and spider mites to some degree.

## Predatory Midges

Predatory midges are fragile-looking and gnat-like (less than 1/8 inch long) with antennae that curl back over their heads. The tiny larvae are yellowish to red-orange (Fig. 172) and are easily seen using a 10X hand lens. Predatory midges are most often found feeding amongst aphids, spider mites, thrips, and the eggs of other insects and mites. Predatory midges are most frequently seen during pest outbreaks. In some parts of the Pacific Northwest, a predatory midge species (*Feltiella* sp.) specialized for feeding on spider mites has been observed. Other species may occur, including *Aphidoletes* spp., which specialize on aphids. Adult predatory midges feed on nectar and honeydew and lay 70 to 200 eggs near aphid or mite colonies. A larva during development consumes 40 to 100 mites or aphids. Pupation occurs on the ground, and pupae overwinter. The life cycle occupies three to six weeks, with three to six generations per year.

Predatory midge adults can be monitored using yellow sticky traps. The value of predatory midges to biological control of spider mite and aphid is significant, particularly when there is an outbreak of these pests. Mid-summer colonies of spider mites in low-input hop yards can be suppressed by predatory midge larvae in combination with other predatory insects and mites. Most broad-spectrum insecticides and miticides used in hop yards are toxic to predatory midges.

## Tachinid Flies

These parasitic flies are gray-black, robust, and have stout bristles on their body similar to house flies (Fig. 173). Tachinids parasitize the caterpillars of moth pests of hop, including armyworms, cutworms, leafrollers, and hop loopers (Fig. 174). Tachinids typically deposit a single egg directly on or inside the body of a caterpillar, and the developing maggot feeds inside the host, eating away non-essential organs first, then emerging from the moribund caterpillar or pupa. The adult fly emerges after two weeks. There are two to three generations a year in Washington, where research has shown they have an impact on hop looper populations. Five species of tachinid fly attack larvae of the hop looper in Washington, with levels of parasitism later in the season up to 30%.

Tachinid flies can be monitored using yellow sticky traps. They are susceptible to pesticides, therefore they should become more frequent in hop yards as broad-spectrum chemical inputs decrease.

Figure 171. Long-legged fly.

Figure 172. Predatory midge larvae are <1/8 inch long.

Figure 173. Tachnid fly.

Figure 174. Hop looper larva killed by a tachinid fly larva, which has now pupated (top). Tachinid fly larva exiting a hop looper larva (bottom). (4 photos D.G. James)

## Pathogens

Naturally occurring diseases sometimes contribute to management of hop pests. In particular, outbreaks of *Bacillus thuringiensis* (a bacterial infection) and viruses occasionally result in population crashes of hop looper. Once pathogens take hold, they can almost eliminate hop looper populations. Diseased caterpillars are easy to spot; they are dark brown to black and hang from one pair of claspers or are draped over leaves (Fig. 175). They emit a foul odor and basically become liquefied, releasing endospores of *B. thuringiensis* to infect other caterpillars. Mites and aphids may also succumb to pathogens, but the incidence of this is generally low in the Pacific Northwest, unless the season is unusually cool and wet.

AT LEFT: Fig. 175. Hop looper larva infected with a bacterium. (D.G. James)

***At a Glance***

**Predatory Thrips**

- Recognize and identify predatory thrips.
- Adults become active among the bines in early spring.
- Predatory thrips can help regulate populations of spider mites, aphids, and moth eggs during mid summer summer.
- Use insecticides and miticides safe to predatory thrips.

# Predatory Thrips

## Description

Thrips are fast-moving, tiny (<1/5 inch) insects with slender, splinter-like bodies, short antennae, and piercing-sucking mouthparts. The adults have indistinguishable fringed, narrow wings that lie together and flat over the body. Three common species of predatory thrips are found in hop yards: sixspotted thrips *(Scolothrips sexmaculatus)*, banded thrips *(Aeolothrips fasciatus),* and black hunter thrips *(Leptothrips mali)*. The six-spotted thrips has three dark spots on each forewing; the banded thrips has three darker bands across each forewing (Fig. 176); and the black hunter thrips is brown-black with opaque, narrow wings (Fig. 177). Larvae are almost colorless to yellow but become darker as they mature. The pupal stage is dark-colored with yellowish-white appendages.

Figures 176 and 177. Banded thrips and black hunter thrips adults. (W. Cranshaw, Colorado State University, Bugwood.org, and D.G. James)

## Biology and Life History

Predatory thrips feed on spider mites, aphids, moth eggs, and pest thrips, producing eight or more generations per year depending on species, prey availability, and seasonal conditions. Adults overwinter in aggregated groups in sheltered locations in and outside hop yards. Adults become active in early spring and search for prey among the developing hop bines. The life cycle may be completed in two to three weeks, and consists of egg, two larval, a non-feeding prepupa, and a pupa stage. Females lay eggs on the underside of leaves, usually near the mid-vein. Prepupae leave the plant and drop to the soil or leaf litter below to pupate.

Predatory thrips can reduce high mite populations, but usually occur too late to prevent damage by themselves. In combination with key predatory insects and mites, predatory thrips can help regulate spider mite populations during spring and summer.

**Predatory Thrips**
**Monitoring, Importance in IPM, and Compatibility with Pesticides**

Predatory thrips can be counted with sticky traps or a hand lens and beating tray. Populations can build rapidly in early to mid-summer. Predatory thrips are generally sensitive to broad-spectrum pesticides.

# Snakeflies and Lacewings

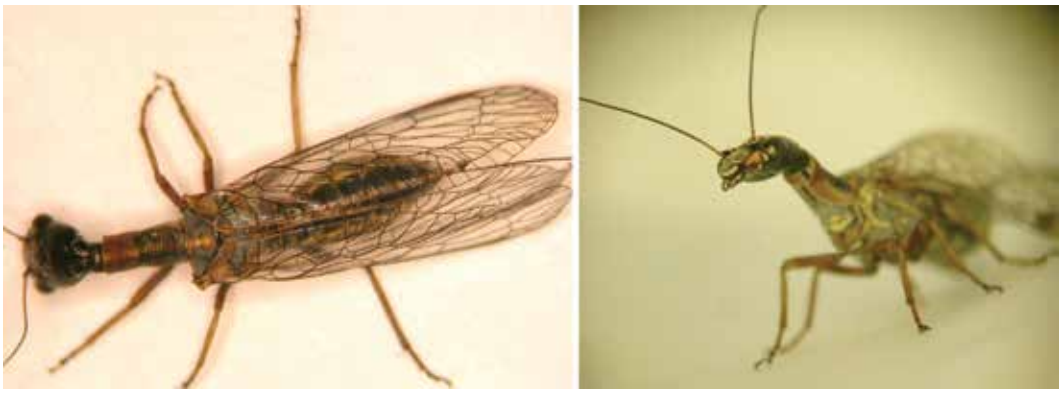
## Description

Snakeflies and lacewings are closely related. Snakeflies' common name derives from the superficially snake-like appearance that is suggested by the unusually long "neck" (frontal thorax) and long, tapering head (Figs. 178 and 179). Snakeflies are voracious feeders of a wide variety of small insects. Adult snakeflies are weak flyers with long, transparent wings.

Lacewings are common predators in hop yards, primarily feeding on mites and aphids. They include *Chrysopa, Chrysoperla,* and *Hemerobius* spp. Adults are soft-bodied, approximately 3/5 to 9/10 inch long, and green or light brown in color). They have long, hair-like antennae and two pairs of transparent, lacy wings netted with fine veins (Fig. 180). The wings fold over the body when at rest. The eyes of green lacewings are golden, and their eggs are small, white, and oblong, each supported on a hair-like stalk approximately 3/4 inch in length (Fig. 181). They are laid singly or

**Snakeflies and Lacewings**
**Monitoring, Importance in IPM, and Compatibility with Pesticides**

Snakeflies and lacewings can be monitored by shaking bines over a tray or by using sticky traps. Along with key predators, their importance in biocontrol is considerable, contributing to suppression of aphids, mites, and loopers. Broad-spectrum pesticides are harmful to lacewings and snakeflies; some newer selective materials appear safer.



Figures 178 and 179. Two views of an adult snakefly. Notice the unusually long "neck" that is a characteristic of these insects. (D.G. James)

in groups. The larvae resemble small caterpillars or lady beetle larvae (Fig. 182). They are fast moving, up to 1 inch long, and spindle-shaped with prominent jaws that project forward. After feeding for a few weeks, pupation occurs within a spherical, parchment-like silken cocoon. Overwintering occurs as prepupae, pupae, or adults. Brown lacewings are generally smaller and more active in spring and fall. Superficially, the larvae are similar to those of green lacewings, but the jaws are not so prominently developed. The stalkless eggs are deposited on leaf surfaces.

## Biology and Life History

The snakefly life cycle has four stages: egg, larva, pupa, and adult. Both larvae and adults are predatory, feeding on aphids, thrips, hop looper eggs, small caterpillars, spider mites, and other small prey. The larvae usually live under tree bark or on the ground in decaying organic material. Snakeflies are arboreal; hop yards provide a good temporary habitat during spring and summer.

Lacewing larvae feed on aphids, thrips, spider mites, and small caterpillars in hop yards. They are frequently found on hop plants and on low-growing vegetation. Green lacewings tend to specialize in feeding on aphids and usually the adults lay their distinctive eggs near aphid colonies. Adult lacewings in the genus Chrysopa are also predatory but adults in other genera require carbohydrate-rich foods such as aphid honeydew or flower nectar or pollen. One to five generations occur per year, with the life cycle occupying four to eight weeks. Adults live for up to three months, producing 100 to 500 eggs.

Figure 180. Adult green lacewing. (D.G. James)

Figure 181. Lacewing egg laid singly on a stalk. (E. Lizotte)

Figure 182. Larva of the green lacewing. Notice the prominent jaws that project forward. (D.G. James)

***At a Glance***

## Snakeflies and Lacewings

- Monitor for lacewings and snakeflies by shaking bines or using yellow sticky traps.
- Consider lacewing presence in combination with lady beetles and predatory bugs for delaying or omitting aphicide sprays.
- The presence of lacewings in a hop yard is a clear sign of low pesticide input.
- Use insecticides and miticides safe to lacewings and snakeflies.

***At a Glance***
**Spiders**

- Spider presence in a hop yard is a good sign of low pesticide input.
- Spiders often serve as buffers that limit initial exponential growth of prey populations.
- Spiders may help regulate aphids and caterpillars.
- Use insecticides and miticides safe to spiders.

# Spiders

## Description

Spiders are common residents in most low-chemical-input hop yards and can reach high densities on the ground floor and in the hop canopy. Some of the common spiders found in hop yards include jumping spiders (Figs. 184 and 184), crab spiders (Fig. 185), sheet web weavers, and sac spiders. Spiders are one of the most abundant predators in hop yards.

## Biology and Life History

Spiders often serve as buffers that limit the initial exponential growth of prey populations. However, the specific role of spiders as effective predators has received little attention and is difficult to demonstrate. There is evidence in many ecosystems that spiders reduce prey populations. They are generalists that accept most arthropods as prey in their webs or in their paths. They eat the eggs and larvae of all the insects and mites that infest hop. Spiders disperse easily to new areas in hop yards and colonize rapidly by aerial ballooning and walking between bines. They are also blown around with wind and debris. The abundance and diversity of spiders in hop yards is linked to the large-scale landscape complexity (i.e., hop yard margins, overwintering habitat, weediness) and local management practices (e.g., pesticide use, tillage practices).

Figure 183. A jumping spider (*Phidippia* sp.) feeding on a beetle larva. (D.G. James)

**Spiders**
## Monitoring, Importance in IPM, and Compatibility with Pesticides

Spiders can be monitored by shaking bines over a tray. The value of spiders to biocontrol is thought to be considerable, but has yet to be evaluated. Most pesticides harm spiders, but populations tend to recover rapidly.

Figure 184. A jumping spider. (D.G. James)

Figure 185. A crab spider on a hop plant. (E. Lizotte)