Habitat Planning for Beneficial Insects

Guidelines for Conservation Biological Control

Jennifer Hopwood, Eric Lee-Mäder, Lora Morandin, Mace Vaughan,
Claire Kremen, Jessa Kay Cruz, James Eckberg, Sarah Foltz Jordan,
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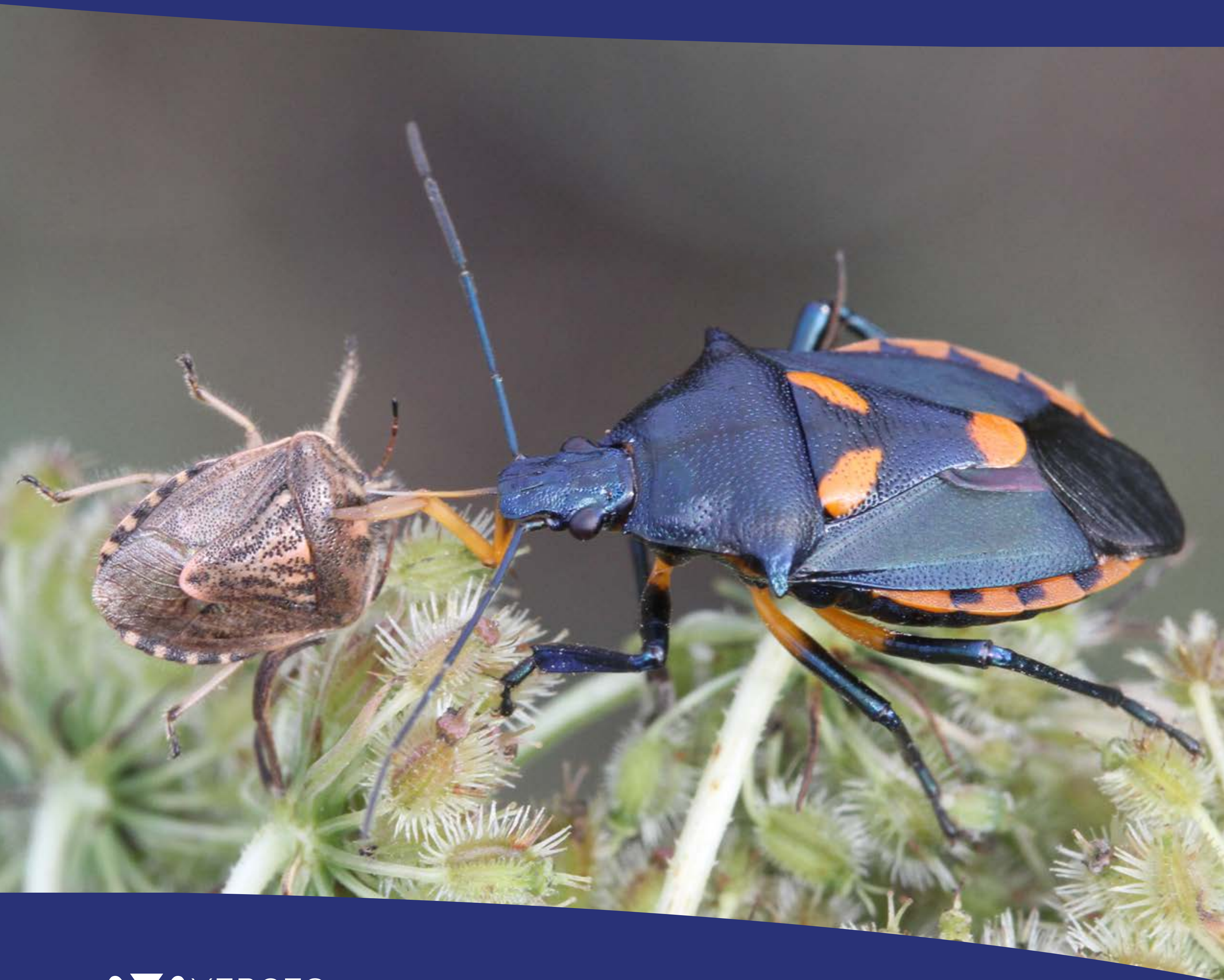

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The Xerces Society for Invertebrate Conservation

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XERCES SOCIETY
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Acknowledgments
This material is based upon work supported by the Natural Resources Conservation Service, U.S. Department of Agriculture (grant number 69-3A75-12-253). Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.

Financial support to the Xerces Society for the development of this guide was provided by the Audrey & J.J. Martindale Foundation, Aveda, Cascadian Farm, Ceres Trust, CS Fund, Disney Worldwide Conservation Fund, The Dudley Foundation, The Elizabeth Ordway Dunn Foundation, Endangered Species Chocolate, General Mills, Irwin Andrew Porter Foundation, Natural Resources Foundation of Wisconsin ATC, SeaWorld & Busch Gardens Conservation Fund, Turner Foundation, Inc., The White Pine Fund, Whole Foods Market and its vendors, Whole Systems Foundation, the Natural Resources Conservation Service (NRCS), and Xerces Society members.

The authors wish to thank Rachel Long, Farm Advisor, University of California Cooperative Extension, Woodland, California; Rufus Isaacs, Professor & Extension Specialist, Department of Entomology, Michigan State University, East Lansing, Michigan; Brett Blaauw, Rutgers Universty; and George Kuepper and David Redhage, Kerr Center for Sustainable Agriculture, for contributing case studies to help illustrate the key concepts in this technical note.

The authors also wish to thank Marcus Miller and Giulio Ferruzzi, USDA–NRCS, WNTSC; Sarina Jepsen, and Scott Hoffman Black, the Xerces Society; Dr. Tessa Grasswitz, New Mexico State University; and Dr. Whitney Cranshaw, Colorado State University, for their careful review of this technical guide.

Editing: Matthew Shepherd, the Xerces Society.

Formatting & layout: Sara Morris, the Xerces Society.

Printing: Print Results, Portland, OR.

Photographs & Artwork
Covers: *front*—Florida predatory stink bug (*Euthyrhynchus floridanus*) feeding on a brown marmorated stink bug (*Halyomorpha halys*) (photograph by John Flannery); *back*—wheel bug (*Arilus cristatus*) feeding on Japanese beetle (*Popillia japonica*) (Photograph by Lisa Brown).

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Introduction

The purpose of these guidelines is to provide recommendations to farmers, conservation districts, USDA Natural Resources Conservation Service (NRCS) field office staff, and other agricultural professionals, when designing and installing habitat features for beneficial insects, those that prey on or parasitize crop pests. Beneficial insects can help suppress populations of pest species, reducing crop damage and reducing the need for insecticides.

Beneficial insect habitat can be supported through many vegetative NRCS Conservation Practice Standards (CPSs). These same installed practices, when designed with beneficial insects in mind, can also support pollinators and other wildlife such as game and songbirds.

Beneficial insect habitat may appeal to farmers (such as some organic producers) seeking to reduce their dependence on chemical insecticides. However, the presence of beneficial insects alone may not solve all pest problems. For comprehensive pest management guidance, farmers should consult with appropriate local extension personnel, integrated pest management (IPM) specialists, certified crop consultants, or other pest management experts.

Background

Wild insects that prey upon or parasitize crop pests are present in vast numbers on farms across the world. In the United States alone, the value of native beneficial insects to crop pest control has been estimated to be at least $4.5 billion annually. Despite this, beneficial insects are often overlooked. This technical note outlines the ecology of beneficial insects and highlights strategies to conserve and enhance their numbers in agroecosystems.

While native predator and parasitoid insects alone may not solve all of a producer's pest problems, they can be part of an IPM system. In general, ongoing research conducted nationwide demonstrates a strong link between conservation of natural habitat and reduced pest problems on farms (Morandin et. al. 2012).

The practice of providing habitat to support abundant populations of naturally occurring insects that attack crop pests is referred to as conservation biological control, or more simply conservation biocontrol. This approach contrasts with classical biological control and augmentative biological control, both of which involve the release of (usually non-native) predator and parasitoid insects into farm fields or greenhouses. Since the introduction of species into new areas raises concerns about their impact on ecosystems, these guidelines focus on conservation biological control as a safer approach that also supports broader conservation objectives.

FIGURE 1: Beneficial insects contribute significantly to natural pest control on farms by attacking and killing a wide variety of crop pests, such as stink bugs.

Because pests and beneficial insects vary among cropping systems and regions, and because of the varying populations at which some beneficial insects provide pest control, these guidelines do not offer specific pest management plans. Rather, the general strategies outlined here are applicable to a wide range of farms.

2 Two-spotted stink bug (*Perillus bioculatus*) feeding on a Colorado potato beetle (*Leptinotarsa decemlineata*), one of its preferred prey.

1

Beneficial Insects

Insects play a major role in farm operations. Although producers sometimes focus on insect pests, the vast majority of insects are beneficial. They recycle nutrients, help decompose plant and animal waste, contribute to soil quality by aerating the soil profile, provide pollination, attack crop pests, and provide a food source for fish, songbirds, and other wildlife.

Insects that perform these functions are generally considered beneficial. In these guidelines, however, the term "beneficial insect" specifically describes insect predators and parasitoids, as well as non-insect arthropod predators like spiders, that suppress crop pests. Sometimes the term "natural enemies" is used to describe these groups. A natural enemy is simply an organism that feeds on another organism. In addition, these groups may also be referred to as "biological control agents." Some people prefer one term over another, but the general meaning of all three terms is the same.

Predators

Within the context of biological control, predators are those animals that hunt and consume agricultural pests. (This is in contrast to parasitoids, explained on the next page.) Economically important predators include insects, spiders and predatory mites, nematodes, birds, and bats. In this document, the focus is on the role of predatory arthropods—insects, spiders, and mites—and ways to enhance their populations.

Predatory arthropods can range in size from four-inch-long mantids (generally known as praying mantises) to tiny mites that are about the size of the period at the end of this sentence. Most arthropod predators are generalists, meaning they feed on a wide array of pests. Individual insects can consume many times their weight in prey; even if they don't seem plentiful in a field, they can still significantly reduce pest numbers.

The diversity of predators in a field crop can be very large. For example, over 600 species of predators (representing 45 families of insects and 23 families of spiders and mites) have been recorded in Arkansas cotton fields, and in the Northeastern United States, 18 species of predatory insects have been found in potato fields. Although the impact of any one type of predator may be minor, their combined impact (along with parasitoids, insect diseases, and beneficial wildlife such as insect-eating bats) can be considerable.

Figure 2: Insect predators hunt, capture and kill other insects for food, such as this polished lady beetle (*Cycloneda munda*) eating an aphid.

Figure 3: Measuring under two millimeters long, *Trissolcus euschisti* is one of few native parasitoid wasp species documented to target the brown marmorated stink bug (BMSB) (*Halyomorpha halys*). Here, it is shown emerging from a parasitized BMSB egg.

Parasitoids

Parasitoids are insects that lay their eggs on or inside another insect. Most parasitoids are wasps, flies, or beetles. After hatching, the parasitoid larva feeds on—and ultimately kills—the host insect before emerging as a fully developed adult.

Some parasitoid wasps are extremely small, less than 1⁄25 of an inch (1 millimeter) in size, making them difficult to see with the unaided eye. Because of their small size, the presence of many parasitoids is not obvious, therefore, careful observation of their hosts or the use of sticky traps (insect monitoring cards) is needed to assess their populations in crop fields. Unlike predators, most parasitoids are specialists, meaning they only attack one or a few host species. Parasitoids also tend to be more susceptible to pesticides than predatory insects, so in order to maintain their populations, care needs to be taken when using pesticides.

Figure 4: The larvae of ectoparasitoids feed externally on their hosts. Some wasp species, like the braconid wasp genera *Digonogastra* sp.[TL] and *Atanycolus*[TR], target boring insects, such as the emerald ash borer (*Agrilus planipennis*). Female *A. cappaerti*[TR] drill through bark and wood with their ovipositor to paralyze a host and lay an egg on it or nearby. After hatching, the wasp larva attaches itself to the host[BR] and feeds until it is ready to pupate[BL] (wasp pupae circled in green, EAB remains in blue). Following metamorphosis, the wasp emerges as an adult.

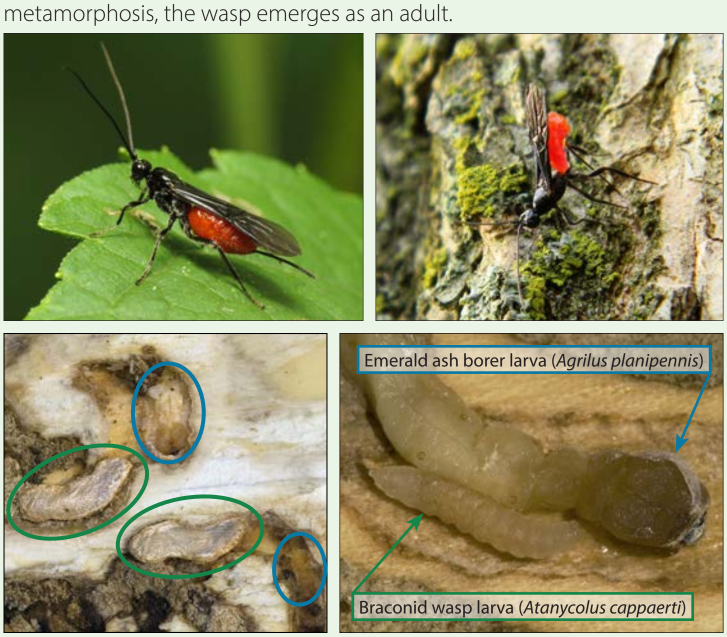


Figure 5: Larvae of endoparasitoids feed internally on their hosts. Wasps of the genus *Meteorus*[TL] specialize in many pest caterpillars, including the gypsy moth (*Lymantria dispar dispar*)[TR]. Female wasps insert numerous eggs into a host. Once the eggs hatch, the wasp larvae will feed on the host internally until they are ready to pupate, when they will emerge from the host[BR]. While many braconid wasps pupate directly attached to their (sometimes still-living) hosts, *Meteorus* pupae hang from or near the deceased host by a silk strand[BL].

2

Benefits of Conservation Biological Control

Farms with adjacent natural or semi-natural habitat tend to have more beneficial insects, less pest pressure, and sometimes, less damage from pests. In general, farms with smaller field sizes, less pesticide use, and more noncrop habitat tend to have the most beneficial insects and may be better able to maintain pest populations below economic thresholds. In addition to simply reducing pest damage, native beneficial insects can provide additional benefits such as reducing the need for insecticides, reducing the need to release non-native biological control agents, and supporting other wildlife.

Reduced Pesticide Use

Beneficial insects can reduce the need for insecticides. Diverse beneficial insect populations can act as insurance against pest outbreaks and the corresponding need for insecticides. With close monitoring of pest and beneficial insect numbers, insecticide use can be reduced and more targeted insecticides can be used. Reducing insecticide use can contribute to safer work conditions and cost savings for producers, and can reduce the probability of pesticide contamination of the environment.

Reduced Dependence on Non-native Biocontrol Agents

The majority of beneficial insects on farms are native, naturally occurring species. In contrast, many pest species are exotic and were introduced by accident. In the absence of natural enemies from their native range, they may reproduce unchecked and cause economic problems in crops. With classical biological control, beneficial insects that prey on the pest in its native habitat are identified. Intentional release of these non-native species *can* provide effective pest control, yet the introduction of non-native biocontrol agents may also produce negative impacts on the natural ecosystem. For example, a parasitoid fly (*Compsilura concinnata*) was released repeatedly in North America between 1906 to 1986 as a biological control against several pests, including the introduced gypsy moth. Now it is implicated in the declines of at

Figure 6: Praying mantis (*Mantis religiosa*) eating a bee. Accidentally introduced to North America from Europe, these indiscriminate predators frequently target beneficial insects.

least six native species of giant silk moths in New England. Similarly, in Hawaii, a recent study revealed that 83% of parasitoids found inside native moths were species that had originally been introduced for biological control of pests[14].

Because of these and other unanticipated effects, classical biological control is controversial. If producers provide habitat for beneficial insects, there is less likelihood that non-native insects will need to be released.

Additional Benefits

Habitats of native grasses and wildflowers created for conservation biological control can benefit farms in other ways. For example, the same habitats that support predators and parasitoids also support crop pollinators such as honey bees and bumble bees. These and other insects, in turn, provide food for other wildlife such as songbirds and game birds.

Native grass and wildflower plantings for conservation biological control can also be incorporated into buffer systems, such as filter strips, grass waterways, and roadside embankments, where they reduce soil loss and improve water quality by filtering runoff from adjacent fields.

Native grass and wildflower plantings can also deprive some crop pests of habitat by reducing their host plants in noncrop areas. For example, in the Pacific Northwest, berry producers are increasingly concerned about the introduced spotted-wing drosophila (*Drosophila suzukii*), a pest of soft fruit. The invasive Himalayan blackberry (*Rubus armeniacus*), a common weed along farm fencerows in the Northwest serves as an alternate host for the fly, increasing its populations even when nearby crops are sprayed with insecticides. To combat the fly, some growers are eliminating the Himalayan blackberry and replanting those fencerow areas with native shrubs that lack fruit on which the fly can reproduce.

Figure 7: Many beneficial insects are attracted to the same plants as pollinators for foraging, nesting, and overwintering. Here, a variety of beneficial insects are foraging alongside native bees and honey bees on giant goldenrod (*Solidago gigantea*).

3

Implementing Conservation Biological Control

Conservation biological control can be thought of as a four-step process:

1. Recognize existing beneficial insects and their habitat.
2. Conserve existing beneficial insect habitat.
3. Provide new beneficial insect habitat.
4. Manage habitat and cropland to minimize harm to beneficial insects.

Step 1: Recognize Existing Beneficial Insects and Their Habitat

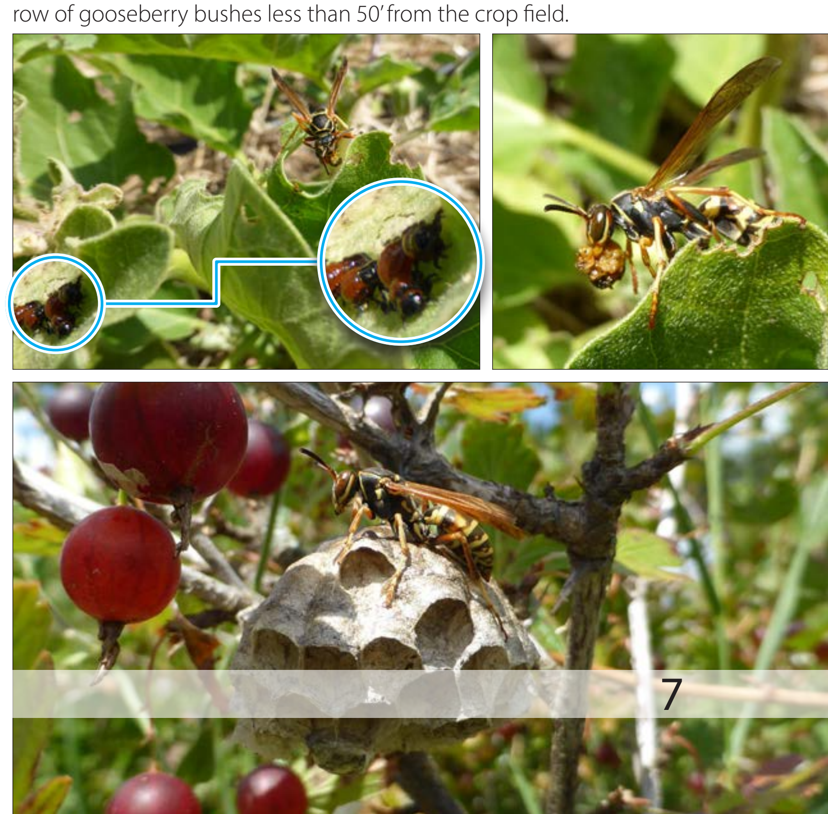
Recognizing which insects prey upon crop pests and their habitat is the first step in conservation biological control. In addition to the basic identification guide included later in this document, local cooperative extension personnel can sometimes offer specific information about locally common beneficial insects. While it is not necessary to know all the species of beneficial insects on a farm, it can be helpful to have a general understanding of their biology. Begin by reviewing the identification guide, Section 7. You will notice that several habitat requirements are shared by many of these species, including the need for:

- Flowers (especially native wildflowers) to provide pollen and nectar as a supplemental source of food, and
- Undisturbed habitat for reproduction and winter hibernation (such as bunch grasses, leaf litter, brush and rock piles, or logs).

Many farms already have these habitat components, especially along roadsides, fencerows, ditches, field borders, and streams; around buildings; and in woodlots and natural areas. Even if these features only occur in small, fragmented patches, taken together they can provide a complex mosaic of valuable habitat. Note that it is important for these patches to be located close to each other, since some insects may not travel more than a couple of hundred yards to hunt for food. It is also important that these areas are protected from pesticide exposure.

Where they are present, wildflower patches

Figure 8: A shorter distance between habitat and prey is more efficient for beneficial insects—such as this paper wasp (*Polistes* sp.), observed bundling up potato beetle larvae[TL,TR] to feed to its young back in its nest[B] located in a row of gooseberry bushes less than 50′ from the crop field.



provide a place to practice identification of locally common predator and parasitoid insects. Look for flowers that have a lot of insect visitors. The best flowers will be easy to spot on warm sunny days when insects are most active. For example, in many areas goldenrod (*Solidago* spp.) is a very important source of late-season pollen and nectar for a huge variety of beneficial insects.

In the case of shelter for reproduction and overwintering, the diversity of predator and parasitoid insect species necessitates a variety of habitat features. Certain wasp species nest underground in dry, sandy soils with sparse vegetation. A number of predatory beetles, on the other hand, will overwinter in the thick crowns of native bunch grasses, or lay their eggs underneath rotting logs. Rather than trying to learn the nesting and hibernation requirements of every beneficial insect species, simply look for undisturbed natural areas with patchy or overgrown vegetation, stumps, snags, rocks, or brush piles. All of them are potential refuge for beneficial insects.

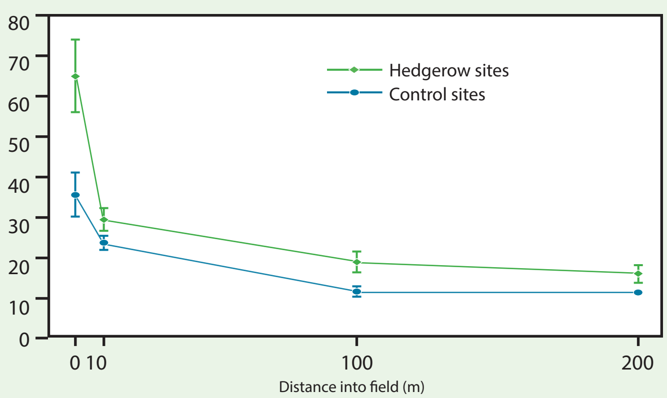
Size of Habitat and Distance to Crops

For most crop systems, the distance that beneficial insect habitat needs to be from crops in order to provide pest control services is not well understood. However, research is demonstrating that crop fields surrounded by an abundance of noncrop habitat tend to have greater beneficial insect populations and lower pest pressure. Also, smaller fields interspersed with natural areas allow beneficial insects to move deeper into crop fields. Because beneficial insects may not travel as far as pests, it is important to create habitat on as many border areas as possible.

Field borders, running the length of a field and only a few feet wide, can increase beneficial insects in adjacent fields. Edge habitats, although not large, will increase predation and parasitism of pests within crops (figures 9 & 10). The extent to which these areas can increase crop yields for many crops by reducing pests or replacing insecticides is less well known.

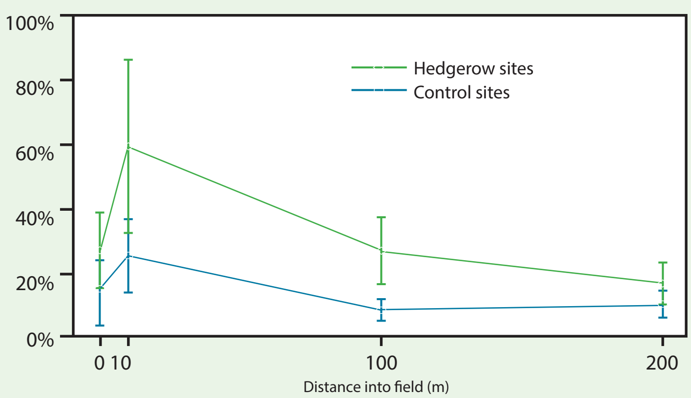
Habitat should be created as close to the target crop as possible in order for beneficial insects to travel into the crop, as long as the habitat is safely away from pesticide drift. Although many predators can travel a considerable distance to colonize agricultural fields, most parasitic wasps will not; some may only travel as far as a few hundred feet.

Figure 9: Parasitoid abundance in tomato fields†



Parasitoids were more abundant tomato fields adjacent to native plant hedgerows than in fields adjacent to weedy control. The vertical axis represents the average number of parasitoids counted on sticky trap cards located various distances from the field edge.

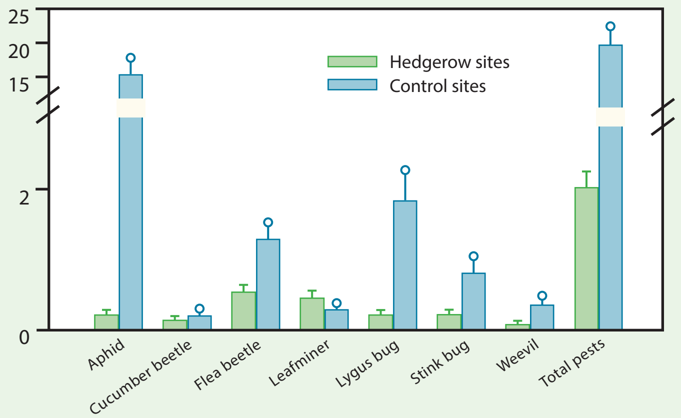
Figure 10: Parasitism of stink bugs in tomato fields†



More stink bug eggs were parasitized and tomato fields adjacent to hedgerows than in fields adjacent to weedy control plots. The vertical axis represents the percentage of parasitized egg masses observed at various distances from the field edge.

† These findings are the result of a multi-year University of California–Berkeley study in Yolo County. The hedgerows consisted of native shrub species, while the control plots used for comparison consisted primarily of non-native field-edge weeds (Morandin et al. 2012).

Figure 11: Crop pest insect abundance†



In sweep net samples of insect activity in hedgerows versus weedy control plots, fewer pests (except leafminers) were observed in the hedgerow study sites.

Figure 12: An example of a native shrub hedgerow in Yolo County, California.

Does Natural Habitat Increase Pest Populations?

Producers are sometimes concerned that habitat for beneficial insects may increase pest populations. For example, native plant field borders may be perceived as a source of weeds. However, careful selection of plants, seeding densities, and spacing can actually result in weeds being crowded out by native plants. This can reduce weed invasions into fields. However, after several years, weeds may begin to reappear in the area and some maintenance will be required.

Similarly, multi-year studies of mature, native plant hedgerows in Yolo County, CA, show that pest insect populations are lower in native plant hedgerows than they are in weedy field edges (figure 11). In addition, the ratio of beneficial to pest insects is much greater in native plant hedgerows than weedy edges, meaning there are more beneficials per pest insect when native plants are present[35].

Non-native weeds, such as Himalayan blackberry, mallow (*Malva* spp.), and wild mustard (*Sinapis arvensis*), are known to harbor pest insects. Himalayan blackberry canes that bend over and touch the ground, for example, provide shelter for stink bugs during the winter. Removal of the non-native blackberry and replacement with native plants can reduce overwintering stink bug populations and infestation in adjacent crops. Aphid populations are also much lower on native vegetation than they are on invasive weeds such as wild mustard.

Step 2: Conserve Existing Beneficial Insect Habitat

Once beneficial insect habitat has been identified, it should be protected from adverse impacts. Where possible, natural areas should not be sprayed with insecticides or herbicides except to control invasive weeds. Stumps, snags, bunch grasses, and brush piles are particularly valuable and should be maintained unless they present a hazard, and mowing should be avoided when wildflowers are in bloom.

Also consider whether the need to remove weeds outweighs their value to beneficial insects. Noxious weeds and weeds that support pest insects should be removed, but some non-invasive flowering weeds can supply essential pollen and nectar food resources and alternate prey, ensuring that predator and parasitoid insect populations remain high even when crop pests are absent.

Step 3: Provide New Beneficial Insect Habitat

Increasing the availability of flowers—especially native wildflowers—is often the single most important strategy for increasing the abundance and diversity of beneficial insects. Like pollinators, such as bees, many insect predators and parasitoids feed on flower nectar or pollen during one or more of their life stages. Syrphid flies, for example, typically feed on aphids during their larval stage, but feed on flower nectar as adults. Some predatory insects also feed on pollen as a supplemental source of protein—often when prey insects are in short supply or to increase the number of eggs they can lay. By increasing the availability of flowers, the numbers, longevity, and reproductive potential of beneficial insects is increased.

Season-long Bloom

A succession of blooming flowers on the farm throughout the growing season provides a stable source of food that beneficial insects need in order to thrive as their prey populations rise and fall with time. Many predators and parasitoids will leave a farm if flower availability is low. Habitat with a diversity of flowers can also provide beneficial insects with alternative prey, allowing them to survive when crop pest populations are low.

Native Plants

Where possible, native plants should be prioritized in conservation biological control efforts. Research by a number of scientists across the country demonstrates that native plants support many times the number of native beneficial insects as non-native plants[17]. Where native plants are not affordable or are only available in limited quantities, non-invasive flowers such as cover crops of annual buckwheat (*Fagopyrum esculentum*) can help supplement the habitat requirements of beneficial insects. A guide to recommended pollen and nectar plants for conservation biological control is included in Chapter 8.

Figure 13: Many flies and wasps exhibit dietary shifts after metamorphosis. Members of the syrphid fly genus Sphaerophoria, for example, feed on aphids as larvae and on pollen and nectar as adults, preferring shallow flowers like golden Alexanders.

Wildflower Selection

Diversity is a critical factor when considering which wildflowers to plant for beneficial insects. Natural flower-rich habitats like remnant tallgrass prairies may have dozens of wildflower species, but conservation areas on farms with as few as 10 carefully chosen plant species can provide a good foundation for attracting a wide variety of beneficial insects.

One way to begin selecting which flowers to plant is to think about the feeding habitats of the various predators and parasitoids that use pollen and nectar resources. Wasps and flies, for example, generally have short tongues and are unable to reach nectar hidden in the deep reservoirs of some flowers. Consequently, nectar-collecting wasps and flies are most frequently observed on shallow flowers with readily accessible nectar such as goldenrods or members of the carrot family, like golden Alexanders (*Zizia aurea*).

Wasps also frequently seek out sugar sources other than nectar, such as honeydew (the sugary excrement of aphids and scale insects), rotting fruit, or the extrafloral nectaries of plants like partridge pea (*Chamaecrista fasciculata*), which secretes nectar at the base of leaf petioles. Beneficial flies also have short mouthparts that are best suited to open or small flowers such as yarrow (*Achillea millefolium*) or cup plant (*Silphium perfoliatum*). Beetles often feed where the pollen and nectar are freely available and there is plenty of perching space, such as on goldenrod. With these general guidelines in mind, if there are particular predators or parasitoids that are desired, identifying and planting their potential host plants may increase their abundance.

In most instances, however, simply trying to support a wide range of beneficial insects by having several plant species flowering at once, and a sequence of plants flowering through the growing season is the simplest approach. If this is the goal, select plants with different flower sizes, shapes, and colors, as well as varying plant heights and growth habits.

Finally, diverse plantings that resemble naturally occurring native plant communities are the most likely to resist pest, disease, and weed epidemics, and thus thrive with minimal care. Observe local natural areas to identify which plants are growing together and seem to have the most floral visitors.

Figure 14: The clusters of small, open flowers on common yarrow attract a variety of beneficial insects with smaller mouthparts, such as tachinid flies.

Figure 15: Goldenrods offer abundant nectar and pollen with easy perching space for beneficial beetle species, like the Pennsylvania leatherwing (*Chauliognathus pensylvanicus*).

Avoid Nuisance Plants

Another consideration in creating new habitat for conservation biological control is to avoid planting species that mainly harbor pests, or those that are susceptible to crop diseases or are weedy. In most instances, crop pests prefer crops to wild native plants. Thus, providing a diversity of native grasses, wildflowers, or shrubs typically benefits predators and parasitoids over crop pests.

While in most instances the recommendation to avoid planting alternate pest host plants is the best course of action, a nuanced and alternative perspective promoted by some researchers recommends purposefully planting such species (known as banker plants) adjacent to farm fields as a way to attract pests away from the crop and thus support a stable population of beneficial insects (usually parasitoids) that prey upon them[11]. This concept assumes that those parasitoids will reproduce in surplus numbers that migrate into crop fields. This concept is likely to be most effective with parasitoids because they require specific pest insects to prey upon, unlike generalist predators that prey upon many types of insects, and can occupy many types of habitat.

Figure 16: Convergent lady beetles (*Hippodamia convergens*) overwinter in large groups, clustered together in bunch grasses and leaf litter, or even under tree bark (inset).

Figure 17: Like bumble bees, queens of vespid wasps—like this western yellowjacket (*Vespula pensylvanica*)—overwinter alone in protected cavities, such as inside or under logs.

Shelter

In addition to nectar, pollen, and prey, beneficial insects need shelter to survive winter or bad weather, to support larval development, and to lay eggs. The preferred types of shelter are not fully known for many species, although it is generally accepted that increasing habitat structure can increase beneficial insect abundance. However, for a few other insects, such as predatory ground beetles, their preferred overwintering sites (bunch grasses on elevated ground) are well understood and steps can be taken to create specific habitat for them, such as creating beetle banks, a method that is described later (Collins et. al. 2002).

Where a farm lacks structural diversity, there are simple steps that can add shelter. Planting fallow ground with native bunch grasses is one way to provide overwintering cover for various predatory beetles. For example, in California, lady beetles are known to cluster inside the clumps of native bunch grasses and under tree bark during the winter. Those same bunch grasses will also help maintain patches of bare ground between clumps that provide access to the soil for predatory ground-nesting wasps. Wood-nesting solitary wasps, on the other hand, nest in the hollow stems of plants like reeds, cup plant, and elderberry (*Sambucus* spp.) or in protected cavities .

Step 4: Manage Habitat and Cropland to Minimize Harm to Beneficial Insects

It is important to maintain the quality of beneficial insect habitat over the long term. The need to control weeds around farm fields, conduct activities like grazing, and simply maintain a good diversity of wildflowers and native grasses in noncrop areas are all important issues to consider.

The best beneficial insect habitat is typically open and sunny, like meadows, prairies, or shrubby areas[3]. Mature forests may provide beneficial insect habitat on their edges, but most forest insects have ecological requirements that differ from those of the common beneficial insects found on farms. Similarly, grassland areas may not have as many beneficial insects if they lack wildflowers and are dominated by only a few species of grasses.

To improve areas of the farm as beneficial insect habitat, conservation planning should prioritize sunny areas with native grasses and wildflowers. Large trees that may shade out native grasses and wildflowers should not be allowed to encroach, and grasses—especially non-native grass—and other weedy plants should not be allowed to reduce overall plant diversity. To achieve this balance, periodic hand-pulling of weeds or spot-spraying with herbicides may be needed. Large weedy trees should be removed if they encroach on restored habitat, or girdled and left standing for beneficial insects and raptors to nest in, if they don't present a safety hazard.

On larger areas, mowing and burning are two common approaches to maintaining diverse grass and wildflower plant communities. If these management practices are used, they should be minimized as much as possible during the growing season so that insects can use pollen and nectar resources. Where mowing is needed, several other strategies can help reduce harm to beneficial insects and other wildlife. These include mowing during the day and use of a flushing bar to help move animals before the blades reach them, cutting at reduced speeds (less than 8 mph), and cutting as high as possible (as high as mower settings allow).

Prescribed livestock grazing may also be a viable option for managing beneficial insect habitat. Ideal grazing patterns are rotational in nature and are designed to create variable ground cover that maximizes native grass and wildflower diversity.

If mowing, burning, or prescribed grazing are used to maintain beneficial insect habitat, harm can be reduced by dividing the on-farm habitat into separate management zones, each less than 30% of the total habitat. Ideally, only one management zone (or 30% or less) of the beneficial insect habitat on each farm should be disturbed in a single year, meaning that each zone has a 3- to 5-year management rotation. This will allow beneficial insects to recolonize disturbed areas from surrounding, undisturbed habitat (Lee et. al. 2001).

Figure 18: Ideally, disturbance to habitat should be limited to 30% or less of the overall area in a single year. This will allow beneficial insects to re-colonize disturbed areas from surrounding, undisturbed habitat.

Grub hunter scoliid wasp (*Triscolia ardens*) nectaring on Arizona milkweed (*Asclepias angustifolia*).

4

Conservation Biological Control Practices

Various general conservation practices can be used to support conservation biological control. For example, many of the same conservation practices used to enhance habitat for pollinators can, with some minor modifications, also be used to improve conditions for other beneficial insects. In general, those practices that provide opportunities to increase wildflower abundance and habitat structure (for nesting and overwintering) should be emphasized. Protection from pesticides is also an important consideration, and is addressed in the next section. Additionally, many NRCS Conservation Practice Standards (CPSs) can be adapted for conservation biological control by farmers, conservation planners, and NRCS staff.

Native Plant Field Borders
[NRCS Field Border (CPS Code 386); Conservation Cover (CPS Code 327)]

On many farms, border areas along crop fields are a convenient place to establish native grasses and wildflowers for beneficial insects. Proximity to crops provides easy movement into fields by beneficial insects, especially smaller species that may not travel long distances in search of food.

Native field border plantings can also reduce weed encroachment into crops by occupying ground that might otherwise be dominated by noxious weed species. Most native perennial grasses and wildflowers are slow to establish, and are unlikely to become weeds in crop fields. However, where weed control is a concern, maintaining mowed strips between wildflowers and the crop can help reduce the spread of plants into crop fields. These mowed strips can also provide areas for moving equipment.

An additional benefit of native grass and wildflower field border plantings is that they can reduce the stunting effect that sometimes occurs along the edges of row crops. At least one study identified improved crop yields in edge rows where field border plantings of native grasses and wildflowers were present. Specifically, such field borders reduce crop competition for light, water, and nutrients when compared to field edges occupied by large trees. Even where no trees are present, grass and wildflower field borders can provide a buffer against wind and reduce runoff from crop fields.

Figure 19: This diverse native plant field border on a California almond orchard provides safe nesting sites and alternative foraging sources throught the growing season for a variety of beneficial insects with different habitat needs.

Field border plantings can take the form of strips along field edges or farm roads, or underneath power lines, and can even be established in the corner areas of center-pivot irrigated fields. Because of the location of these areas, and their proximity to crops, it is especially important to protect all field border plantings from pesticide drift.

Establishment of permanent native grass and wildflower field borders usually requires a full year of site preparation to remove existing weeds and create a clean, relatively weed-free planting site. Site specific conditions, such as soil type, sun or shade exposure, drainage, and local native plant distribution, should be factored into field border planting plans. See Table 1 (page 66) for some common native wildflowers used in field borders in various regions.

Temporary Insectary Strips

[Cover Crop (CPS Code 340); Herbaceous Wind Barriers (CPS Code 603); Upland Wildlife Habitat Management (CPS Code 645)]

A more intensive conservation biological control strategy is to plant strips of temporary pollen and nectar plants within the crop field itself. This strategy is sometimes used by organic lettuce producers in California who plant entire rows of sweet alyssum at regular intervals between rows of lettuce to support predators and parasitoids of aphids. Depending on the arrangement of insectary strips, they can provide multiple benefits by supporting beneficial insects, reducing soil erosion, and protecting growing crops from damage by windborne particles.

Because insectary strips are temporary—placed within crop fields that will later be cultivated—producers should focus on low-cost, rapid-blooming annual species. Recommended species typically include bachelor's button (*Centaurea cyanus*), dill (*Anethum graveolens*), coriander (*Coriandrum sativum*), lacy phacelia (*Phacelia tanacetifolia*), buckwheat (*Fagopyrum esculentum*), and alyssum (*Alyssum* spp.).

Insectary plantings are usually established at the time of the primary crop planting and plowed up at the end of the season. While they can significantly enhance populations of pollen and nectar feeding beneficial insects, their temporary nature does not provide overwintering shelter. Combined with permanent native grass and wildflower field borders, however, mass insectary plantings may provide corridors that help move beneficial insects out of field edges and directly into the crop itself, enhancing pest control throughout the entire field.

Since insectary plantings are usually integrated into crop fields, it is imperative that they not be exposed to insecticides, including some organic-approved insecticides. For this reason, they should only be used by producers who do not apply insecticides or where pesticide drift is easily controlled. See Table 4 (page 72) for common low-cost flowering species used for temporary insectary plantings.

FIGURE 20: Planting insectary strips with low-cost, non-invasive annual flowers—such as cilantro—can attract and sustain beneficial insects before and after a crop's peak bloom until the end of the season.

FIGURE 21: For more effective pest control on this organic vegetable farm in North Carolina, insectary strips of crimson clover (*Trifolium incarnatum*) are planted between crop rows.

Hedgerows and Windbreaks

[Hedgerow Planting (CPS Code 422); Windbreaks/Shelterbelt Establishment (CPS Code 380); Tree and Shrub Planting (CPS Code 612)]

A hedgerow is a long linear row of flowering shrubs and small trees, sometimes with wildflowers and grasses in the understory. Hedgerows are typically located along property boundaries, fence lines, roads, and as barriers to physically separate crop fields.

Windbreaks are very similar to hedgerows, although typically planted with taller growing species to better reduce wind velocity. Hedgerows and windbreaks have long been recognized for their many farm benefits including providing habitat for wildlife and pollinators, capturing runoff from adjacent agricultural lands, and providing renewable sources of firewood and harvestable wild fruits and herbs.

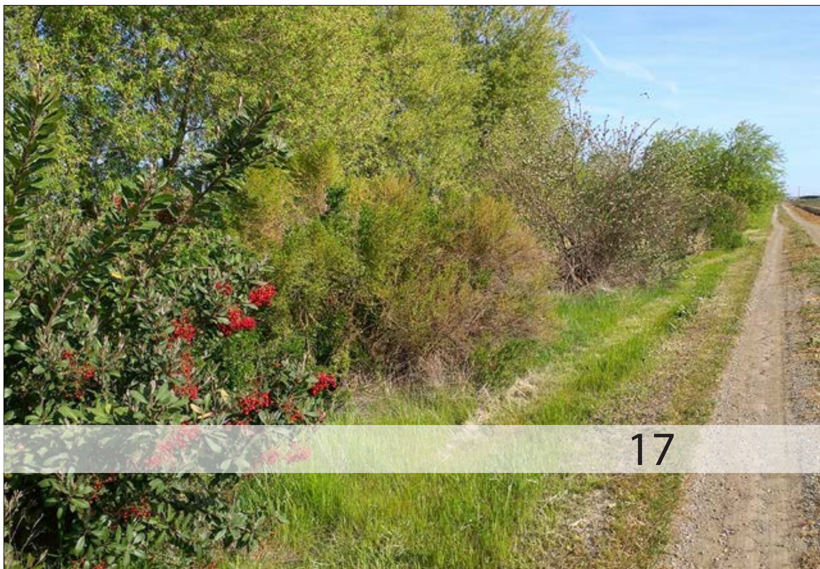
The hedgerow concept is thought to be more than 4,000 years old, having originated in Europe to mark property boundaries (often the remnants of cleared woodland) and to provide living fences for livestock. European hedgerows are characterized by various styles associated with their respective region—sometimes growing on top of earthen banks and supported with stacked stones, and often with ditches running the length of the hedgerow sides.

Hedgerows have become increasingly popular in parts of the United States, and are often constructed along roads where they can help reduce dust or along irrigation ditches to help stabilize the soil. Flowering trees and shrubs in hedgerows can maintain those primary conservation functions while at the same time supporting an abundance of beneficial insects. See Table 2 (page 68) for some common native flowering trees and shrubs used as hedgerow plants in various regions. Native flowering vines can also be incorporated into hedgerows, along with various native grasses and wildflowers (consider shade-tolerant species for north-facing sides of hedgerows). In some cases, where availability of native plants is limited, cost prohibitive, or for droughty, exposed sites unfavorable to native species, non-invasive exotics can also be used. For example, rosemary (*Rosmarinus officinalis*) and Russian sage (*Perovskia atriplicifolia*) are two widely available non-native plants that flower prolifically; tolerate dry, exposed locations; and form small shrubs in warm climates.

In most cases, hedgerow plants are established from transplants or live-stake cuttings. Transplants usually need supplemental irrigation for the first two years after transplanting, along with regular weeding and sometimes protection from browsing by deer or rodents. Transplanted shrubs may also require several years of establishment before they begin flowering. If immediate pollen and nectar resources are desired, a hedgerow can be "jump-started" by interseeding wildflowers between the transplanted shrubs or in rows adjacent to the sides of the hedgerow. As the shrubs mature, they will crowd out some of the area occupied by wildflowers, but begin to produce more of their own flowers.

Long-term hedgerow management usually consists of removing invasive weeds or cutting back large trees that shade out other hedgerow species. In Europe, larger hedgerow species are sometimes cut back to the ground and allowed to resprout (called coppicing) to produce multiple, bushy stems. Another practice, called hedgelaying, involves cutting most of the way through upright trunks, then bending the partially attached trunks over at an angle in line with the hedgerow. The laid trunks form a strong barrier, and new growth from the stumps and trunks results in thicker hedgerow structure and fills in gaps where other shrubs may have died.

Figure 22: This California hedgerow comprised of native flowering shrubs and bunch grasses offers a variety of resources to beneficial insects, including alternate food sources, safe nesting habitat, and undisturbed overwintering sites.



Windbreaks and Hedgerows as Pesticide Buffers

Hedgerows consisting of dense evergreen trees like spruce and arborvitae will do little to support most insect predators and parasitoids. However, those plants can provide wind screening and reduce pesticide drift from adjacent cropland.

Pesticide screening may be an especially important consideration for organic producers adjacent to conventional farms. For more information about designing hedgerows and windbreaks, see the books, websites, and other resources listed on pages 75 and 76.

Cover Crops
[Cover Crop (CPS Code 340)]

Cover crops are temporary plantings of ground cover in crop fields, between rows of berry crops, or in the understory of vineyards and orchards. Like hedgerows, cover cropping can have multiple conservation objectives, including reducing erosion, improving soil fertility, preventing weed growth, and providing pollen, nectar, and shelter for beneficial insects.

Common cover crops include various legumes, grasses, and brassicas. Of these groups, legumes are widely recognized for their contribution to soil fertility as green manure crops; grasses are noted for their ability to capture excess soil nutrients, prevent weed growth, and reduce erosion; and brassicas are commonly used to absorb excess nutrients, alleviate soil compaction, and to suppress soil pests like nematodes. Additional cover crops—such as lacy phacelia and buckwheat—are used for various applications, including the support of beneficial insects. Depending on the objectives, several different cover crop species can also be seeded together to provide complementary benefits.

Legume cover crops that provide pollen and nectar for beneficial insects include perennial species such as red, white, and alsike clovers (*Trifolium* spp.); biennial species such as sweet clover; and annual species like crimson clover, berseem clover, and hairy vetch (*Vicia villosa*). Other less commonly cultivated legume cover crops are available that may be appropriate for certain climates. In some cases, native legumes are also available for cover crop purposes, such as partridge pea (*C. fasciculata*), a native annual that attracts numerous beneficial insects and forms a thick canopy.

Common grass cover crops include cereal rye (*Secale cereale*), wheat (*Triticum* spp.), and oats (*Avena sativa*), all of which can provide valuable overwintering cover and mulch layers for beneficial insects. These cover crops are often planted in fall and allowed to either winterkill (in the case of oats), or resume growth in the spring (when they are usually terminated and the field then replanted with cash crops). These same cool season annual grasses are also often mixed with annual legumes like crimson clover (best in warm climates) or hairy vetch (for colder winter climates) to form a complimentary cover crop that builds soil organic matter, adds nitrogen, and more effectively protects fallow ground from erosion. This type of combined grass–legume cover can greatly increase benefits to beneficial insects by providing a complex of both flower resources and shelter.

Brassica cover crops (*Brassica* spp.) include several species of rapeseed (*B. napus*), mustards, and forage radish (*Raphanus sativus*, sometimes called oilseed or daikon radish). A growing body of research demonstrates that brassica roots produce chemical compounds (called glucosinolates) that suppress weed growth, soil-borne plant diseases, and nematodes. Many brassicas are annual or biennial species, and will only flower—providing pollen and nectar resources for beneficial insects—if they are actively growing in the spring or early summer. This timing can be complicated by the fact that brassicas are often planted in the fall as a cool-weather cover crop and allowed to winterkill (most brassicas are not winter hardy and will die at around 25°F). Thus, if brassicas are intended to support beneficial insects, they are best used in spring and summer cover crop systems or for year-round use in warmer climates. A few cooler weather varieties may be available in some areas (consult a plant materials specialist), and brassicas can be interseeded with grasses and legumes (ideally at a low rate because of their competitiveness) to form a complementary cover crop. Note that, a few brassicas—primarily black mustard (*B. nigra*)—can have weedy tendencies and they can be an alternate host for cabbage root maggot, flea beetles, and several other pests, as well as clubroot disease of cruciferous vegetables. Consult a local vegetable crop expert if these are potential concerns.

Two other cover crops that are common in some areas are buckwheat and lacy phacelia. Buckwheat, a broadleaf annual frequently grown as a grain crop, matures in 30–45 days. This rapid growth allows it to be used on fallow fields to outcompete annual weeds. When allowed to mature, buckwheat flowers prolifically and provides an abundance of nectar to syrphid flies, parasitoid wasps, and other beneficial insects. Because of its rapid development, two sowings of buckwheat can be performed in a typical summer season. It does not grow vigorously in cool weather, however, so local planting times should be adjusted accordingly. Buckwheat also produces large volumes of seed and can become temporarily weedy when allowed to self-sow. To control volunteer seedlings, buckwheat should be mowed before seeds fully develop.

Figure 23: Flowering cover crops like buckwheat[T,BR] and lacy phacelia[BL] are a simple way to provide large amounts of pollen and nectar for beneficial insects, like lady beetles (shown: *Hippodamia convergens*).

Lacy phacelia is a native California wildflower that is used as an annual cover crop for both weed suppression and capture of excess soil nitrogen. Low-cost seed is now widely available from organic seed suppliers and bulk wildflower seed vendors. Lacy phacelia produces large numbers of flowers per plant that continue to open in succession over a period of several weeks. Strip-mowing or successive seeding of phacelia can further extend the flowering period. Large numbers of bees are attracted to phacelia, but syrphid flies and various beneficial wasps are also common flower visitors. Phacelia winterkills at 20°F, requiring spring planting in cool climates; in warmer climates it can be fall sown for spring bloom. Like buckwheat, phacelia can become weedy if allowed to self-sow (especially in warm climates). Mowing before seed maturation can reduce volunteer seedlings.

Common cover crop species for various regions of the country are listed in Table 4 on page 72. Many other cover crops are available for specific uses and may be useful for providing pollen and nectar resources or shelter for beneficial insects. Local seed suppliers and a cooperative extension should be consulted for more options. Remember that if conservation biological control is a primary goal, it is essential to wait until most flowers have bloomed before tilling or mowing a cover crop.

Conservation Cover

[Conservation Cover and Meadows (CPS Code 327)]

In perennial crop systems such as vineyards and orchards where the ground will not routinely be cultivated, producers can maintain permanent ground covers of native grasses like Junegrass (*Koeleria macrantha*), side oats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), blue wild rye (*Elymus glaucus*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and Idaho fescue (*Festuca idahoensis*).

Once established, these tough, drought-resistant grasses are highly effective at controlling weeds between rows and withstanding equipment traffic, and will provide permanent cover for beneficial insect species. When necessary, these native grasses can be periodically mowed and interplanted with perennial cover crop legumes (e.g., red clover) or native wildflowers to further support beneficial insects. Common species for various regions of the country are listed in Table 3 on page 70.

Herbaceous Buffer Practices

[Contour Buffer Strips (CPS Code 332); Field Border (CPS Code 386); Filter Strip (CPS Code 393); Grassed Waterways (CPS Code 412); Herbaceous Wind Barriers (CPS Code 603)]

Other places where beneficial insect habitat can be incorporated into farm systems include drainage ditches, embankments, or areas of permanent vegetation near fields and roads, that capture surface runoff and filter out sediment, excess nutrients, or agrochemicals.

The primary purpose of these and other farm buffer systems should never be compromised. However, in some cases they can be constructed with a variety of native plants to also provide functional beneficial insect habitat. For example, a grassed waterway is a graded channel of land that is stabilized with permanent vegetation and designed to carry surface water runoff to a suitable location (such as a pond, wetland, or drainage basin). The vegetation covering a grassed waterway helps slow runoff velocity, preventing soil erosion. Sod-forming grasses are the best vegetation for this purpose because they can be mowed periodically to maintain hydraulic function. In some cases, however, simply leaving the side margins unmowed will provide beneficial insects with shelter and allow room for taller native bunch grasses and perennial wildflowers or small shrubs.

Figure 24: This Washington vinyard maintains native perennial grasses like bluebunch wheatgrass and Idaho fescue as a permanent understory that provides habitat for beneficial insects while also preventing weed encroachment.

Figure 25: This native wildflower buffer strip between fields on a Montana grain farm provides beneficial insect habitat in addition to reducing wind velocity, runoff, and the spread of wind-blown weed seed.

In others, even within the mowed center of a grassed waterway itself, tough low-growing, wildflowers that tolerate occasional mowing like yarrow (*Achillea millefolium*) or lanceleaf coreopsis (*Coreopsis lanceolata*) can be seeded into sod-forming grasses. Because of the aggressive growth habitat of the grasses, these wildflowers will not dominate a waterway but can enhance pollen and nectar resources.

Tunnel Nests, Beetle Banks, and Brush Piles

[Cross Wind Trap Strips (CPS Code 589c); Vegetative Barrier (CPS Code 601); Herbaceous Wind Barriers (CPS Code 603); Upland Wildlife Habitat Management (CPS Code 645); Structures for Wildlife (CPS Code 649)]

A final conservation biological control strategy is to provide shelter for beneficial insects for overwintering survival, egg-laying, and pupation. Common types of shelter include the crowns and understories of tall bunch grasses, thick piles of dead brush, decomposing logs, stumps and snags, and similar features.
The exact shelter requirements for the vast majority of beneficial insects are largely unknown, however, so the best advice is to leave diverse, uncultivated habitat in places where it already exists. Beyond that, intentionally constructed piles of brush, logs, fieldstones, and other natural materials may provide shelter for beneficial insects.

For a few groups of beneficial insect, more specific shelter enhancement strategies are available. These include tunnel nest structures for solitary wasps, beetle banks for predaceous ground beetles, and brush piles for a variety of beneficial insects.

Tunnel Nests

Tunnel nest structures for solitary wasps are identical to those constructed for solitary wood-nesting bee species, such as mason bees and leafcutter bees. In general, tunnel nests are constructed by drilling a series of dead-end holes into a wood block and hanging it from a barn, fence post, tree, or other above-ground structure. Unlike nest blocks designed for solitary bees, tunnel nests for wasps may attract more nesting insects if the holes are relatively small in diameter (e.g., ⅛" for wasps that gather aphids). However, offering a range of hole sizes between ⅛" and 5⁄16" in diameter and 4–6" deep will likely attract a diversity of wasp species, as well as solitary bees. Such nests should be sheltered from rain, placed above the height of surrounding vegetation, in a sunny location, and ideally near a visual landmark such

Figure 26: Many sphecid species (shown: *Isodontia* sp.) will use the same artificial nesting blocks as solitary bees—each female wasp will construct individual cells in a tunnel using mud, grass, or resin, and provision them with prey.

Figure 27: Close-up of wasp tunnel nests in an artificial nesting block—where female sphecid wasps constructed individual chambers using mud, then provisioned each cell with paralyzed leaf beetle larvae[T] or spiders[B]., before laying an egg and enclosing it.

as a large tree or along a hedgerow. Various solitary wasps in the families Vespidae and Sphecidae are common inhabitants of these structures, provisioning their nests with beetle grubs, caterpillars, aphids, and even grasshoppers. To reduce the build up of disease spores, nest blocks should be replaced every few years, and old nest blocks discarded.

Beetle Banks

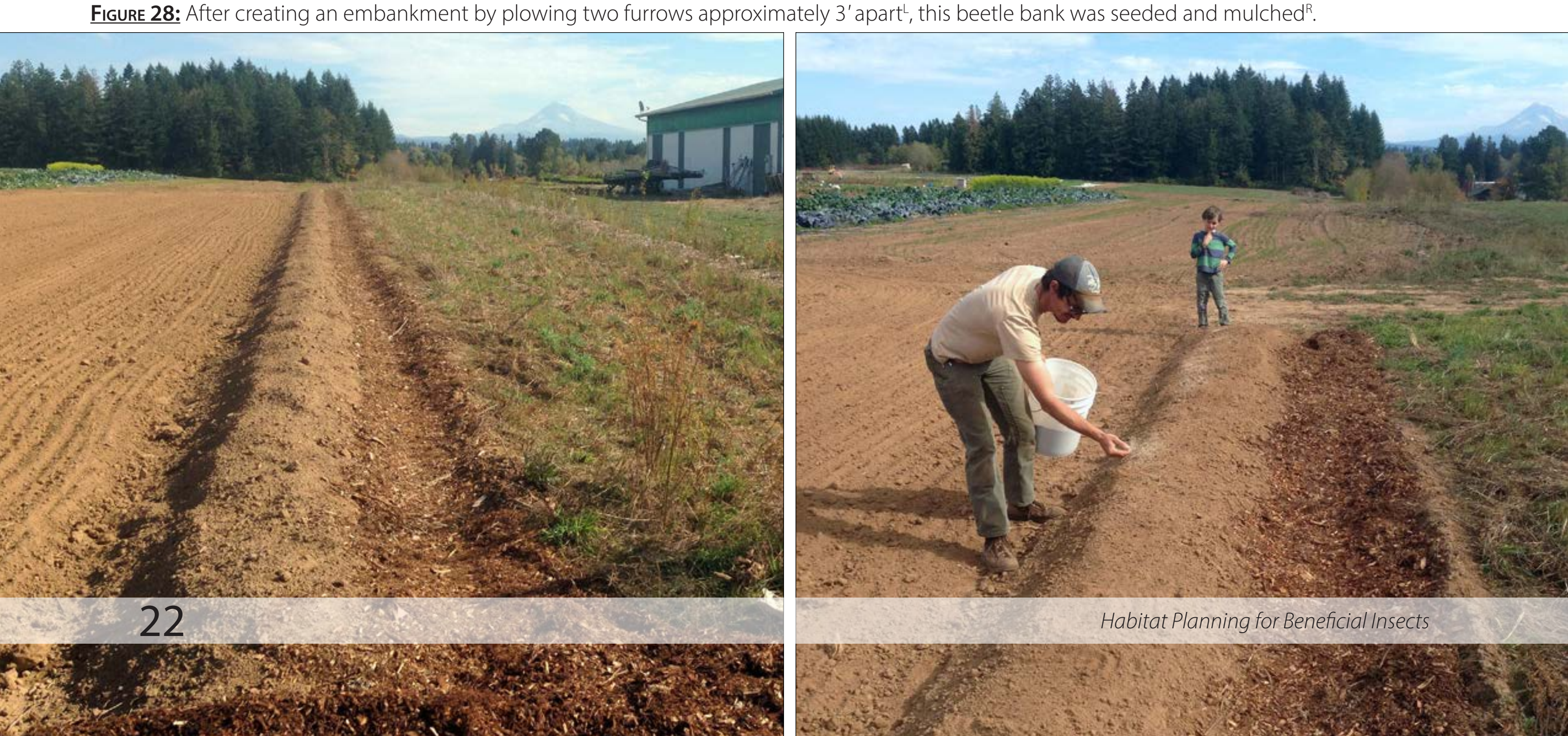
Beetle banks provide shelter for predatory ground beetles. Beetle banks consist of long, elevated earthen berms planted with perennial bunch grasses (and occasionally interplanted with native wildflowers). These banks provide winter cover for ground beetles adjacent to fields that are cultivated, and are intended to promote rapid movement by beetles into crop fields when warm weather returns the following year.

The beetle bank concept originated in Europe to provide habitat for beetles and other beneficial insects that have declined due to the loss of hedgerows and other natural habitat adjacent to cropland. British farmers have used the beetle bank concept to successfully control grain crop pests like aphids and wheat blossom midges—in some cases eliminating the need for pesticides. Additional research suggests that various ground beetle species supported by beetle banks may feed extensively on weed seed, and can play an important role in suppressing crop weeds. Despite these promising results, beetle banks remain largely untested in the United States.

Beetle bank construction is usually performed by plowing two reverse furrows side-by-side to create an embankment between 2–6′ wide, and at least 1′ high. The bank is then seeded with native bunch grasses (or transplanted grass plugs). In western states, blue wild rye, California oatgrass (*Danthonia californica*), slender wheatgrass (*Elymus trachycaulus*), and Roemer's fescue (*Festuca roemeri*) are some of the grass species that have been used in beetle bank construction. In other regions, native bunch grasses like switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardi*), little bluestem, Indian grass (*Sorghastrum nutans*), Junegrass, and prairie dropseed (*Sporobolus heterolepis*) are good candidates.

Beetle banks are often positioned in the center of crop fields and extend almost to the field edges (leaving enough room on each end to turn around equipment). In this way, the entire field around the beetle bank can continue to be cultivated. The size of a crop field may necessitate multiple beetle banks positioned at regular intervals to account for the dispersal distance of ground beetles and other beneficial insects. Current guidelines in Britain recommend at least one beetle bank per 50 acres, ideally placed in the center of the field with enough space at either end for equipment to pass (RSPB 2008).

Figure 28: After creating an embankment by plowing two furrows approximately 3′ apart[L], this beetle bank was seeded and mulched[R].



New beetle banks will often require mowing during the first year after planting to suppress annual weeds that may shade and compete with the newly established bunch grasses. Ongoing management in future years will require control of woody plants and spot-spraying or spot-pulling weeds. Over time, as the grasses mature, they should reduce weed encroachment. As with all beneficial insect habitat, it is important to protect beetle banks from insecticide spraying.

Beetle banks are still a new concept in the United States, but they closely resemble a number of soil conservation structures, including NRCS CPS Codes 589C, Cross Wind Trap Strips; 601, Vegetative Barrier; and 603, Herbaceous Wind Barriers.

Brush, Log, and Stone Piles

Constructed piles of brush, logs, or fieldstones will provide shelter and overwintering habitat for some beneficial insects. Begin your brush pile by placing the larger branches or logs on the bottom, along with any stones, so that the pile has a sturdy base. Continue to stack branches and logs, layering them crosswise with small limbs and brush on the top, or pile branches in a conical shape around a central big log. As the brush pile settles, you can add to it or create a new pile. Good locations for brush piles include field borders, hedgerows, wooded edges, or fence corners. Several smaller but well-placed brush piles are more beneficial than a single large pile. Create two piles per acre, or more for areas with little natural cover.

Brush pile construction for wildlife—including beneficial insects—and the construction of wood block nests for solitary bees and wasps may be supported through CPS Code 645, Upland Wildlife Habitat Management, or Code 649, Structures for Wildlife.

Figure 29: Constructed from deadwood and stones, these habitat piles on Minnesota farms are safe locations in which beneficial insects can overwinter.

Whirlygig mite (*Anystis spp.*) feeding on a a fungus gnat.

5

Reducing Harm from Pesticides

Integrated pest management (IPM) is a decision-making framework that can assist in reducing unnecessary pesticide use. IPM employs five steps:

1. Reduce conditions that favor pest populations (pest prevention).
2. Monitor and scout for pest and beneficial insect populations.
3. Identify insects (both pests and beneficial insects).
4. Determine action thresholds for making treatment decisions.
5. Control pests <u>only</u> when the threshold is reached.

The goal of IPM is to reduce pest populations while also minimizing risk to the environment and other organisms, like beneficial insects. This can be accomplished by stressing pest prevention and incorporating control tactics only when a demonstrated need exists.

The NRCS can assist farmers with the adoption of IPM programs through the conservation planning process. Additionally, the NRCS can help reduce nontarget impact of pesticides by using the Windows Pesticide Screening Tool (WIN-PST) to assess the potential risk to water quality from pesticide leaching, solution runoff, and pesticides adsorbed to sediment. While WIN-PST does not evaluate pesticide risk to predatory or parasitoid insects, it does have a bee toxicity component in its database that can help provide a larger picture of the potential risk to nontarget organisms. For more information about using the bee toxicity component in WIN-PST, see the NRCS publication, *Agronomy Technical Note 9: Preventing or Mitigating Potential Negative Impacts of Pesticides on Pollinators Using Integrated Pest Management and Conservation Practices*.

Pesticide Risk Reduction

Insecticides impact beneficial insects through both lethal and sublethal effects, such as inhibiting foraging, reproduction, and nesting. Even herbicides, most of which are not toxic to insects, can reduce habitat by eliminating native grasses and wildflowers that support beneficial insects.

If insecticides must be used, apply when beneficial insects are least active. Most beneficial insects prefer daylight hours for active feeding, so nighttime spraying with active ingredients that have short residual toxicities is one strategy for reducing harm. (Note: Residual toxicity of many insecticides can last longer in cool temperatures, and dewy nights may cause an insecticide to remain active on the foliage the following morning. Also note that some very important pest predators, including most predaceous ground beetles, are nocturnal.)

Whenever an application is made, drift should be controlled to prevent poisoning of beneficial insects (and other wildlife) in noncrop areas. Drift occurs when spray droplets, pesticide vapors, or wind-borne contaminated soil particles are carried on air currents outside of the crop field. In some cases, pesticide drift may be limited to only adjacent field border areas (a problem if you are trying to maintain those areas as beneficial insect habitat). In more extreme cases, pesticide drift has been known to cause damage more than a mile from the site of application. Factors affecting the extent of drift include weather, application method, equipment settings, and the physical properties of the active ingredient.

Weather-related pesticide drift increases with greater wind velocity, higher temperatures, and stronger convection air currents, and also during temperature inversions (i.e., when air is dead calm and trapped close to the ground). The effects of wind can be minimized by spraying during early morning or in the evening when winds are calmer. Pesticide labels will occasionally provide specific guidelines on acceptable wind velocities for a particular product.

Mid-day spraying can sometimes increase risk because as the ground warms, rising air can lift the spray particles in vertical convection currents. Such droplets can remain aloft for some time and can travel many miles. During temperature inversions, spray droplets can also become trapped and move laterally above the ground, in a cool, lower air mass. Inversions often occur when cool nighttime temperatures follow high daytime temperatures and are often characterized by foggy conditions.

Optimal spray conditions for reducing drift occur when the air is slightly unstable with a very mild steady wind of 2–9 mph. Ideally, temperatures and humidity should be moderate. Contact your local cooperative extension for region-specific guidance.

Spray application methods and equipment settings also strongly influence the potential for drift. Since small droplets are most likely to drift long distances, aerial applications and air-blast sprayers should be avoided whenever possible. Standard boom sprayers should be operated at the lowest effective pressure and with the nozzles set as low as possible. Nozzle type also has a great influence on the amount of drift a sprayer produces. Select nozzles capable of operating at low pressures (15–30 psi) to produce larger, heavier droplets that will deliver the insecticide within the crop canopy where it is less likely to be carried by wind currents.

Figure 30: Non-flowering trees and shrubs are ideal for windbreaks because they are less likely to attract beneficial insects, in addition to buffering no-spray habitat from pesticides.

New electrostatic spray applicators can also help reduce off-target pesticide applications by applying the pesticide with special nozzles that "charge" the droplets, which are then electrically drawn to the plant surfaces. This approach delivers chemicals more effectively and efficiently than with traditional nozzle technology, and can reduce off-target application by over 50%. Regardless of the chemical or type of application equipment used, sprayers should be properly calibrated to ensure that excess amounts of pesticide are not applied.

Finally, non-flowering windbreaks and conservation buffers can be effective barriers to reduce pesticide drift from neighboring fields. For example, windbreaks of dense evergreen trees—such as spruce (*Picea* spp.) or juniper (*Juniperus* spp.)—which typically attract relatively few beneficial insect species, can be a barrier for reducing pesticide drift and protecting adjacent beneficial insect habitat.

6

Conservation Biological Control Case Studies

Beneficial Insects Thrive in Hedgerows on California Central Valley Farms
By Rachael Long, Farm Advisor, University of California Cooperative Extension

In the heart of California's Sacramento Valley, Yolo County growers are on the forefront of a movement to plant hedgerows. For example, in 2010, nearly six miles of new hedgerows were planted in Yolo County alone, representing 40% of the total length of hedgerows planted in California and 10% nationally. These corridors of vegetation primarily surround field crops, including canning tomatoes, wheat, alfalfa, and seed crops that are worth over $200 million annually.

There are many reasons why growers choose to plant hedgerows on their farms. Some like the biodiversity they bring to intensively farmed areas. Birds and other wildlife frequent the hedgerows, providing wildlife viewing and game hunting. The flowering shrubs and berries produced in the hedgerows are also visually attractive throughout the year, especially after the harvest and the ground is disc harrowed in preparation for the next crop. Landowners are also interested in hedgerows for weed control on field margins and for windbreaks and preventing soil erosion, which in turn, helps improve air and water quality.

There is significant interest in the enhanced pollination and pest control that the beneficial insects thriving in hedgerows can provide to adjacent crops. Long-term studies in Yolo County have shown that hedgerows of flowering plants and native grasses attract a wide variety of predators and parasitoids that feed on the nectar and pollen.

Figure 31: Bordering an organic tomato production field in California's Central Valley, this blooming hedgerow consists of native shrubs, grasses, and forbs that not only support natural predators for pest control, but also beautify the area.

Figure 32: Drought-tolerant native plants, such as buckwheat (top) and gumplant (bottom), thrive in California Central Valley hedgerows at the height of summer, attracting a variety of beneficial insects.

Figure 33: Native hedgerows support more than beneficial insects, they attract various wildlife and pollinators—such as monarch butterfly caterpillars (*Danaus plexippus*), shown here feeding on California narrowleaf milkweed (*Asclepias fascicularis*).

These beneficial insects include lady beetles, big-eyed and minute pirate bugs, and parasitic and predatory wasps and flies, which have been documented moving long distances into adjacent crops where they can help improve pest control. Although hedgerows can attract pests, such as stink bugs, cucumber beetles, flea beetles, and lygus bugs, they also support a proportionately far greater population of beneficial insects than is found in weedy field margins (see figures 9–11 on pages 14–15).

Most growers choose to plant native California shrubs and perennial grasses in hedgerows including California lilac (*Ceanothus* spp.), buckwheat (*Eriogonum* spp.), toyon (*Heteromeles arbutifolia*), elderberry (*Sambucus* spp.), coffeeberry (*Rhamnus californica*), coyotebrush (*Baccharis pilularis*), western redbud (*Cercis occidentalis*), purple needlegrass (*Nassella pulchra*), purple oniongrass (*Melica spectabilis*), and blue wild rye (*Elymus glaucus*). These plants are drought tolerant and thrive well under California's hot, dry summers with minimal irrigation in most soils. Most of the hedgerows are planted along field margins in areas that cannot be farmed, so no land is taken out of production. This includes along streams, canals, fence lines, and areas where differences in field height occur from land leveling. Most hedgerows are linear with a row of shrubs bordered by perennial grasses, as these are easiest to care for with large-scale farm equipment—including mowers—for weed control.

The interest in hedgerows and corridors of vegetation surrounding farms is continually growing in our area as landowners learn about them and become aware of their many benefits. Numerous field days, workshops, field trips, Natural Resource Conservation Service financial assistance programs, and a wealth of experience by conservationists in Yolo County are making this possible. Seeing hedgerows thriving in intensively farmed areas of California's Central Valley adds a richness of biodiversity to our landscapes, as well as potential economic benefits from beneficial insects that thrive in these living corridors.

Growing Blueberries While Making Farms Better for Beneficials

By Rufus Isaacs, Professor and Extension Specialist and Brett Blaauw, Rutgers University Department of Entomology

At Wind Dancer Blueberry Farm in Grand Haven, Michigan, there has been a slow but steady transition towards a more biologically-based approach to farming. Richard "RJ" Rant is bringing plant diversity into his farm as part of a long-term approach towards more sustainable farming. As part of this approach he is designing components to support beneficial insects, but that's only a part of the story. The biological system that RJ is designing will feed the soil to improve the nutrition of his bushes while bringing balance to the farm environment.

Figure 34: Blueberry bushes flourish alongside buckwheat and crimson clover, which attract beneficial insects and pollinators while suppressing weed and enriching the soil.

To increase plant diversity within the rows of his 60-acre blueberry farm, he has included different plant mixes for different situations. RJ has planted Dutch and New Zealand white clovers (*Trifolium repens*) in areas that need to withstand farm traffic. Buckwheat and crimson clover (*Trifolium incarnatum*) are planted in alternate rows between the blueberry bushes. In the fall he is planning several new insectary plantings between the rows, including one that will be planted with Michigan native wildflowers and grasses and another to be planted with carrot (*Daucus carota* ssp. *sativus*), chervil (*Anthriscus cerefolium*), coriander (*Coriandrum sativum*), clovers, nasturtium, parsley (*Petroselinum crispum*), alyssum, and yarrow.

Under the blueberry bushes, he is experimenting with a mix of crimson, white, and alsike clovers that have short root systems that may outcompete weeds without competing with the shallow-rooted blueberry plants. These are used in part because their flowers support beneficial insects, including bumble bees that pollinate blueberry, but more importantly for RJ, the clovers fix nitrogen and provide acidic root exudates for the acid-loving blueberry plants. On top of this, they build organic matter in his sandy soils providing a longer-release source of nutrients for the blueberry plants than fertilizers and making them more resistant to drought. RJ has been able to decrease his irrigation use by 4–5 hours because of this increase in moisture retention. Although cover crops may be seen as expensive at first, RJ finds this is a cheaper approach compared to the $7 a yard of wood chips (plus the cost of hauling) and $4 a gallon for diesel to run his irrigation pump.

Along with the clovers under the bushes, to combat weeds and support beneficial insects, RJ is also testing diverse plant mixes of yarrow, brassicas, turnips (*Brassica rapa*), oats, and common vetch (*Vicia sativa*). Overall, RJ aims to put 5% of his property into habitat that will provide weed suppression, soil nutrients, and overlapping blooms through the season to help beneficial insects prosper on his farm. He sees this diversity above ground as also being good for diversity below ground, helping to support beneficials in both realms for the improvement of his farm and the environment. After five years of this transition to bringing diversity into his blueberry growing system, RJ is seeing the benefits in the form of a reduced need for insecticides even while he is maintaining yields and keeping pests in check.

Habitat for Beneficials on an Oklahoma Farm and Ranch

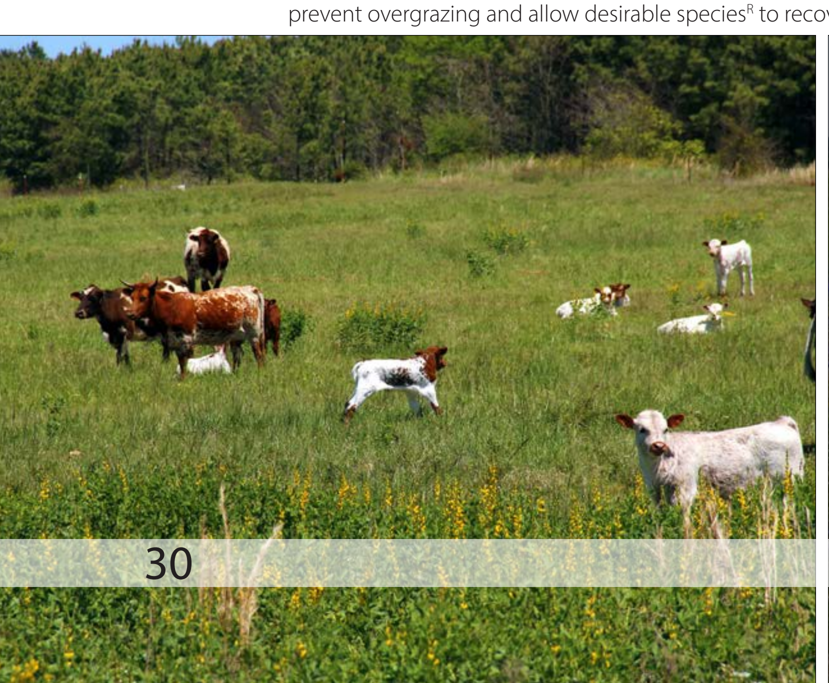
By George Kuepper, Horticulture Manager, and David Redhage, Director of Ranch Operations and Natural Resources, Kerr Center for Sustainable Agriculture

Though often overlooked as a resource for smaller wildlife, rangeland and native pastures can be carefully managed to supply diverse and abundant flowering plants, which in turn can support beneficial insects. At their 1,776-acre farm and ranch in southeast Oklahoma, the nonprofit educational foundation Kerr Center for Sustainable Agriculture demonstrates the integration of economic and ecological goals. Managing grazing animals, pasture, and rangeland is important in Oklahoma, where cattle are the number one farm commodity and are commonly raised on both small and large.

The Kerr Center implements rotational grazing (also known as controlled grazing or management intensive grazing), a practice used to maintain soil fertility, improve forage quality, and extend the grazing season on pasture land. Goats, cattle, pigs, and poultry are rotated through pastures at the Kerr Center. Pastures are grazed intensely for brief periods of time, followed by long rest periods. Although some especially palatable wildflowers cannot withstand the pressures of intensified grazing, others are able to recover and bloom during the rest periods. Due to multi-species and rotational grazing, preliminary observations indicate that there is increased biodiversity on the ranch and that during the growing season something is always in bloom. This includes native wildflowers such as wild indigo (*Baptisia* spp.) and ironweed (*Vernonia* spp.), as well as yarrow, coreopsis, Mexican hat (*Ratibida columnifera*), and winecup (*Callirhoe involucrata*). These flowers all provide pollen or nectar for predatory and parasitic insects. Introduced species such as arrowleaf clover and hairy vetch are also attractive to both beneficial insects and pollinators.

In addition to their pastures, the Kerr Center also grows organic horticulture crops, including heirloom vegetables. Numerous practices used at the Kerr Center support beneficial insects. Alternatives to insecticides, such as kaolin clay, are used to protect heirloom tomatoes from pests and reduce the impact on beneficial insects. Organic insecticides like neem and pyrethrum are used as a last resort and are spot-sprayed to limit the exposure of pollinators and other beneficials to otherwise harmful materials. Cover crops, such as rye and vetch, are planted for winter cover, and sudan grass (*Sorghum* × *drummondii*) and cowpeas (*Vigna unguiculata*) are grown in the summer. These cover crops shelter and sustain beneficial insects throughout the year. Insectary plantings of buckwheat and annual sunflowers provide additional pollen and nectar during the summer and early fall. Beetle banks have been planned for the organic site, and habitat plantings of native perennial wildflowers intended to support predators, parasitoids, and pollinators are currently being established.

Figure 35: Angus-Gelbvieh cross cattle[L] are moved from pasture to pasture as part of a rotational grazing program designed to prevent overgrazing and allow desirable species[R] to recover between rotations.



7

Common Beneficial Arthropods

There are numerous groups of beneficial arthropods native to North America, including certain types of flies, wasps, beetles, true bugs, lacewings, spiders, and mites. These wild insects and arachnids contribute significantly to natural pest control on farms, which is why it is important to correctly identify which beneficial arthropods prey upon crop pests. The following identification guide will help producers and conservationists become familiar with common groups of beneficial arthropods that are found across North America. For more information on locally and regionally common species, contact your local cooperative extension.

Beneficial Insect Life Cycles

Different insects go through different stages of development as they mature, which can make identifying immature beneficial insects of certain species difficult. Since the larval stage of many beneficial insects is the most predaceous, it is important to be familiar with the life cycles of common beneficial insect groups in order to correctly identify and protect beneficial insect larvae.

Groups of insects such as true bugs and mantids go through incomplete metamorphosis—a transition from egg to nymph to adult that doesn't include a pupal stage. Nymphs frequently resemble adults, but are smaller, wingless, and cannot reproduce. Other groups, such as beetles and flies, undergo complete metamorphosis—passing through four stages of egg, larva, pupa, and adult. The larvae usually do not resemble adults and can occupy different habitat.

Figure 36: Clockwise from top left: assassin bugs do not pupate. Females lay eggs in clutches on branches or leaves; after hatching, nymphs go through numerous instars until they are fully mature.

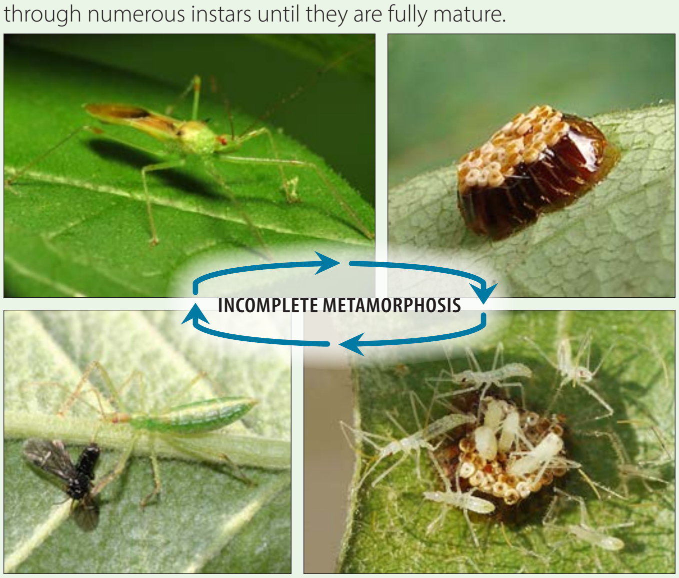
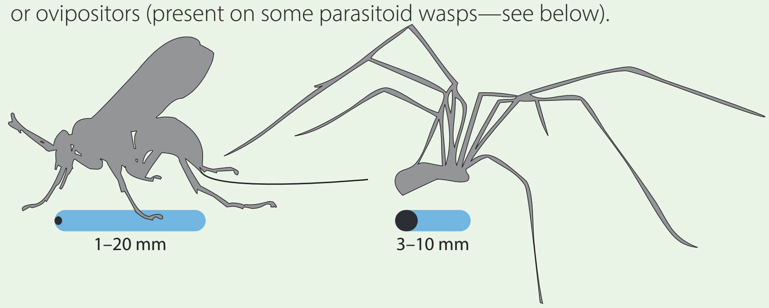


Figure 37: Clockwise from top left: lady beetles oviposit clusters of eggs; after hatching, larvae go through several instars before becoming pupae, when they develop into adults.

A Note About ADULT SIZE

Adult Size refers to *average* adult **smallest** and **largest** body length measurements. It does not include appendages, such as legs, antennae, or ovipositors (present on some parasitoid wasps—see below).



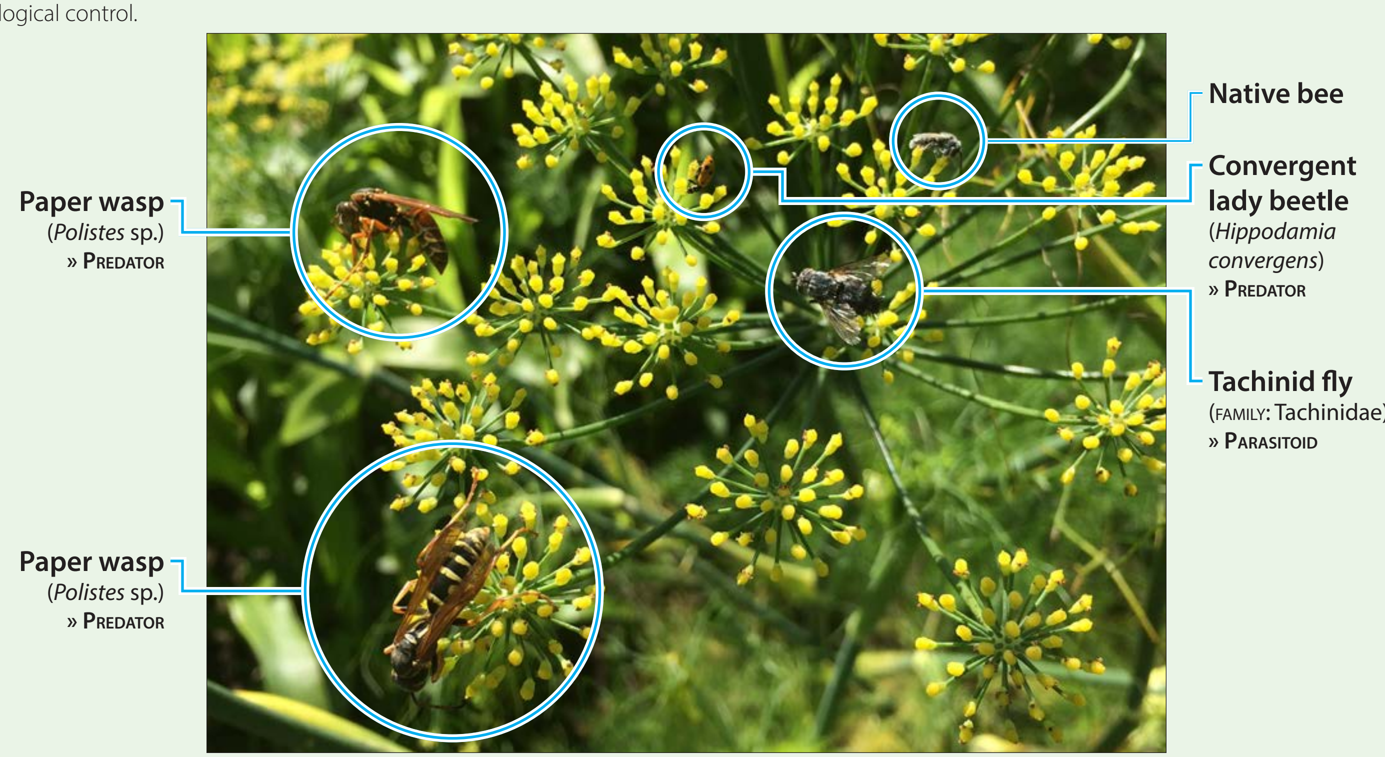
How to Use This Guide:

This section will help you recognize different groups of beneficial arthropods—organized by insect predators, parasitoids, and non-insect predators—with basic identification information, natural history, life cycle, and most common prey or hosts.

Glossary of Terms:

- **ADULT SIZE**—**smallest** and **largest** body length measurements, see sidebar.
- **DIET**—generalist (no documented limitations), specialist (diet is limited to a specific species or pest group), or semi-specialist (diet is limited to one or more pest groups and their allies).
- **COMMON PREY**—the most frequently documented target species/groups, which may include other beneficial insects. (*Note: this is not comprensive and may differ from local populations*).
- **SPECIES**—the number of species in North America.
- **DEVELOPMENT**—the average amount of time from egg to adult.
- **GENERATIONS PER YEAR**—the average number of generations produced per year.

FIGURE 38: Accurately identifying insects in the field is essential to successfully conserving beneficial insect groups. Confronted with the five insects below (shown feeding on dill), many observers wouldn't realize that all are beneficial insects, including four that are highly desirable species for conservation biological control.



Assassin Bugs, Ambush Bugs [ORDER: Hemiptera; FAMILY: Reduviidae]

» Assassin Bugs

ADULT SIZE: 5–36 mm

IDENTIFICATION: Adult assassin bugs are long, small- to large-sized insects that may be drab gray or brown or brightly colored, with an elongated head and a slender beak that is used to pierce prey.

» Ambush Bugs [SUBFAMILY: Phymatinae]

ADULT SIZE: 5–12 mm

IDENTIFICATION: Adult ambush bugs are smaller and often possess raptorial forelegs that are enlarged and spiny to grasp prey. Many species have varied coloration that often acts as camouflage.

DIET: Assassin and ambush bugs are generalist predators that will often kill more prey than they need. Wheel bugs (*Arilus cristatus*) are especially valuable predators of caterpillars and Japanese beetles (*Popilla japonica*).

COMMON PREY:

- Aphids
- Grasshoppers
- Caterpillars
- Beetles
- Bees
- Wasps
- Flies
- Various other insects

SPECIES: 150+ (combined)

DEVELOPMENT: 4+ weeks

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 1

OVERWINTERING: As eggs, nymphs, or adults at the base of plants, under leaf litter, or behind tree bark.

PRIMARY HABITAT: Eggs are laid on leaves or branches of plants.

FIGURE 39: Assassin and ambush bugs will drink nectar when prey is unavailable—like this *Pselliopus cinctus* observed drinking nectar on goldenrod.

CONSERVATION STRATEGIES: Assassin and ambush bugs dwell on flowers waiting for prey. They may drink nectar when prey is scarce and also can benefit from the shelter provided by insectary plantings or hedgerows.

FIGURE 40: Wheel bugs are predacious as adults and nymphs. Clockwise from left: adult feeding on a Japanese beetle, early instar nymph feeding on a weevil, and late instar nymph feeding on beetle larva.

FIGURE 41: Lurking unseen among the flowers of common boneset (*Eupatorium perfoliatum*), this jagged ambush bug (*Phymata* sp.) caught a blow fly.

Big-eyed Bugs [ORDER: Hemiptera; FAMILY: Geocoridae (GENUS: *Geocoris*)]

FIGURE 42: Big-eyed bug nymphs[T] resemble adults[B], but are smaller, lack wings, and may be lighter colored.

FIGURE 43: Big-eyed bugs primarily feed on a variety of sucking insects, such as whitefly larvae[L]; but, they will also forage on flower pollen when prey is scarce[R].

ADULT SIZE: 2–5 mm

IDENTIFICATION: Adult big-eyed bugs are small, oval in shape, and are so named for their bulbous eyes that project from the side of the head and help them spot their prey. These bugs are black or pale in color, and nymphs resemble adults except they are smaller and lack wings. Both nymphs and adults are predaceous, with piercing, needle-like mouthparts.

DIET: Generalist predators of eggs, nymphs or larvae, and adults.

COMMON PREY:

- True bugs
- Beetles
- Caterpillars
- Flies
- Thrips
- Mites

SPECIES: ~25

DEVELOPMENT: ~50 days

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 1+, varies with species

OVERWINTERING: As adults in thatch or under low-growing plants

PRIMARY HABITAT: Eggs are deposited on leaves or in the soil near potential prey.

CONSERVATION STRATEGIES: Permanent plantings of bunch grasses or shrubby garden plants like oregano or thyme can provide winter shelter for big-eyed bugs. Flowers that provide nectar and seeds can sustain big-eyed bugs when prey is limited. A refuge from tillage is important so that overwintering big-eyed bugs can persist.

Damsel Bugs [ORDER: Hemiptera; FAMILY: Nabidae]

ADULT SIZE: 3–12 mm

IDENTIFICATION: Damsel bugs are small, with long slender bodies that range from golden-brown to grey or black coloration. They have needle-like mouthparts and enlarged, raptorial forelegs for grasping prey—similar in appearance to assassin bugs. Damsel bug nymphs are smaller, wingless versions of the adults. The small, cylindrical, cream-colored eggs are laid into plant tissue.

DIET: Generalist predators

COMMON PREY:

- Caterpillars
- Aphids
- Leafhoppers
- Leaf beetles
- Thrips
- Spider mites
- Insect eggs

SPECIES: 40

DEVELOPMENT: 5+ weeks

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: <5

OVERWINTERING: In meadows or crop fields under debris or litter as adults or as eggs

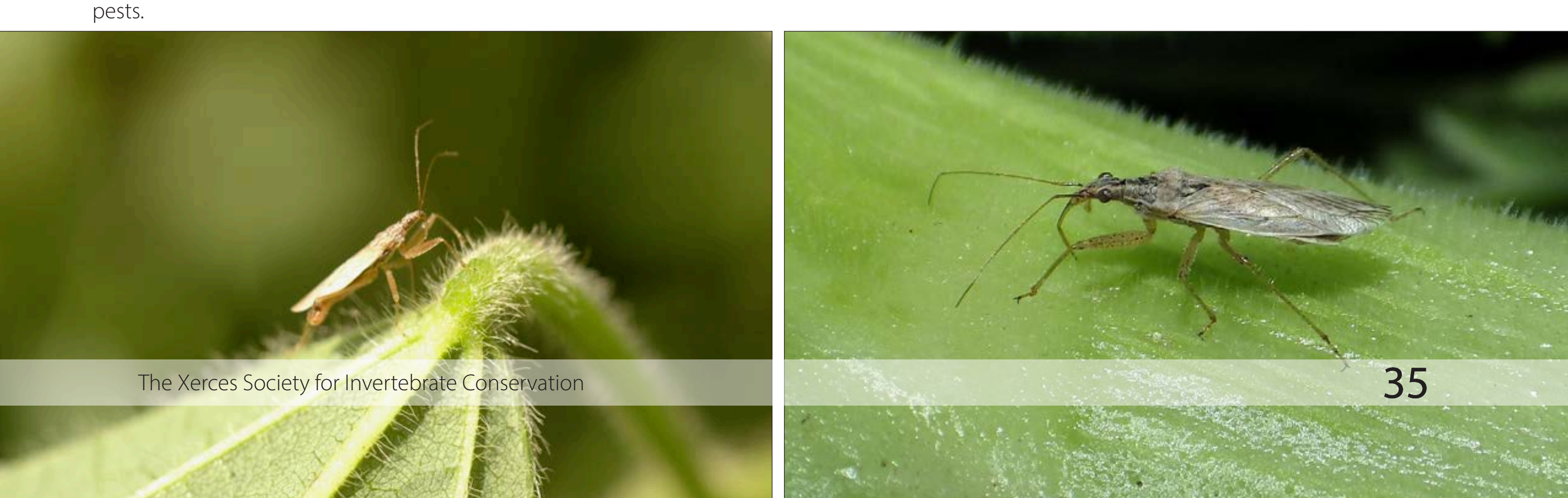
PRIMARY HABITAT: Crop debris, mulch, or brush piles

CONSERVATION STRATEGIES: Provide and protect habitat in which damsel bugs can find sources of alternate prey and places to overwinter: meadows, pasture, grasslands, and grassy areas around gardens and near crops. According to research, damsel bugs are more abundant in no-till systems over tilled systems and in intercropped systems where two or more crops are grown together over single-species plantings.

FIGURE 44: Damsel bugs are long and slender[L] with piercing mouthparts[R] and raptorial front legs.

FIGURE 45: Damsel bug eggs are laid into plant tissue, such as the undersides of leaves[TL]. After hatching, nymphs (shown: *Nabis subcoleoptratus*) go through several instars (the number varies by species) as they mature[R,LL].

FIGURE 46: Damsel bugs are commonly found in fields, gardens, and row crops—such as soybeans[L] and squash[R]—where they hunt for a variety of pests.



Minute Pirate Bugs [ORDER: Hemiptera; FAMILY: Anthocoridae]

FIGURE 47: Minute pirate bugs have distinctive triangular-patterned wings[L], and needle-like mouthparts[R] (inset).

FIGURE 48: Minute pirate bug (*Orius insidiosus*) nymphs are wingless, usually brown or orange, and quite small. Below, a nymph is feeding on soybean aphids (*Aphis glycines*) nearly its own size.

ADULT SIZE: 2–5 mm

IDENTIFICATION: Adult minute pirate bugs have a flattened oval-shaped body, a triangular black head, triangular patterns on the wings, and needle-like mouthparts used to puncture prey. Nymphs are brown or orange, have teardrop-shaped bodies, are wingless. Both the nymphs and adults are predaceous.

DIET: Generalist predators; pirate bugs can consume around 30 small insects or eggs per day, and excel at seeking out prey at low densities.

COMMON PREY:

- Thrips
- Mites
- Scales/ mealybugs
- Aphids
- Plant lice
- Small caterpillars (e.g., bollworm, corn earworm)
- Various insect eggs

SPECIES: ~100

DEVELOPMENT: 3+ weeks. Note: development can be slowed by cooler temperatures or lack of prey

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 2–3

OVERWINTERING: Adults overwinter in leaf litter or under bark.

PRIMARY HABITAT: Leaf litter, herbaceous vegetation, trees

CONSERVATION STRATEGIES: Minute pirate bugs can be supported through the maintenance of permanent plantings within or near crops, and through protection of natural grassland or wooded areas nearby. Habitat with herbaceous or shrubby plants can provide shelter and alternate food sources. Particularly attractive flowers include plants in the bean, sunflower, and carrot families, as well as willows, elderberry, and buckwheat. Crop diversity can also increase minute pirate bug populations.

ADDITIONAL FOOD SOURCES: Pollen, nectar, and some plant sap

Predatory Stink Bugs [ORDER: Hemiptera; FAMILY: Pentatomidae, SUBFAMILY: Asopinae]

ADULT SIZE: 7–25 mm

IDENTIFICATION: These true bugs are easily recognized by their shield-shaped bodies, but are named for the unpleasant smelling substance released from glands on the side of their thorax. The majority of stink bug species are plant feeders (some of which are pests), but those in the subfamily Asopinae are predators that range in size from 7–25 mm. Predatory stink bugs have a beak which is thick at the base, a characteristic that can help distinguish them from plant feeding stink bugs, whose beaks are slender at the base.

DIET: Generalist predators; predatory stink bugs have been documented to target over 100 insect species

COMMON PREY:

- Various insect eggs
- Larvae of numerous crop pests, including the Colorado potato beetle, Mexican bean beetle, European corn borer, diamondback moth, corn earworm, beet armyworm, fall armyworm, cabbage looper, imported cabbageworm, velvetbean caterpillar, and flea beetles
- True bugs (e.g., brown marmorated stink bug, southern green stink bug)
- Other small soft-bodied insects (e.g., alfalfa weevil, diaprepes root weevil)

SPECIES: ~35

DEVELOPMENT: 7+ weeks

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 1+; varies with species and location

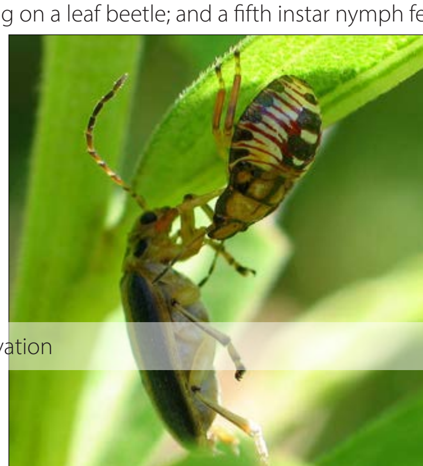
OVERWINTERING: As eggs or adults in litter

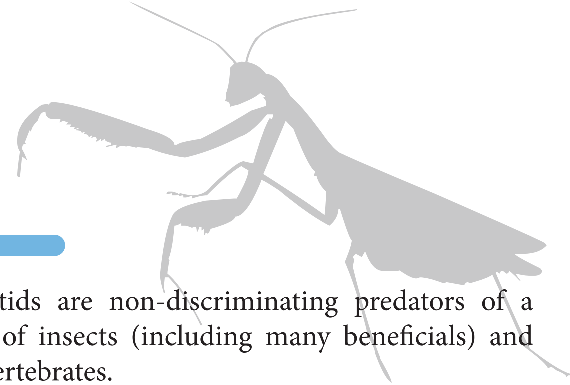
FIGURE 49: Predatory stink bug species are desirable beneficial insects because they target so many crop pests—many of which are notoriously difficult to control, such as Colorado potato beetle larvae[T] and Mexican bean beetle larvae[B].

PRIMARY HABITAT: Predatory stink bugs can be found in field crops, meadows, hedgerows, and forest edges. They may occasionally feed on nectar and possibly pollen. Eggs are laid in clusters on vegetation.

CONSERVATION STRATEGIES: Native plant buffers can provide alternate prey and critical shelter for overwintering eggs or adults.

FIGURE 50: Left to right: barrel-shaped predatory stink bug eggs are laid in large clusters on vegetation and the rotund, early instar nymphs can easily be mistaken for beetles; a third instar nymph feeding on a leaf beetle; and a fifth instar nymph feeding on a webworm.





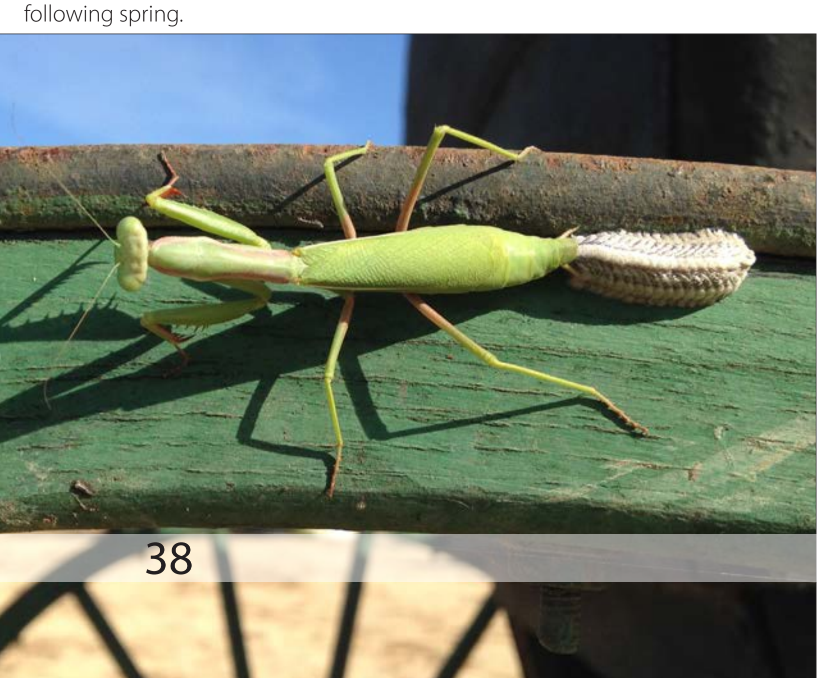
Mantids [ORDER: Mantodea]

ADULT SIZE: 50–100 mm

IDENTIFICATION: Mantids, often referred to as praying mantises, have distinctive, spiny raised front legs, a triangular head, and an elongated body. Mantids are typically green or brown in color, making them well camouflaged in vegetation. Mantids also have excellent eyesight and can turn their heads 180°, which aids them in hunting prey. However, they are not very effective biological control agents because they feed indiscriminately (see note, below right).

FIGURE 51: Chinese mantis perched on dotted mint (*Monarda punctata*). This introduced species is increasingly more common than many native species.

FIGURE 52: Female mantids lay eggs in an ootheca, or egg case, in the fall. Each ootheca can contain up to 100 eggs that will hatch the following spring.



DIET: Mantids are non-discriminating predators of a variety of insects (including many beneficials) and small vertebrates.

COMMON PREY:

- Aphids
- Grasshoppers
- Beetles
- Bees
- Wasps
- Caterpillars
- Flies
- Small insects
- True bugs
- Butterflies & moths
- Various other insects

SPECIES: 20

DEVELOPMENT: 10–12 months

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 1

OVERWINTERING: As eggs, enclosed in an ootheca attached to plant stems or other surfaces (figure 52)

PRIMARY HABITAT: Most mantid species are ambush predators that wait on flowers or foliage for prey to come within reach. Some native species in the southwest are ground hunters that run their prey down on smooth stone or sandy soil.

CONSERVATION STRATEGIES: Mantids that reside on flowers produce more eggs and have a higher body mass than mantids that dwell on nonflowering plants. Eggs are laid in groups of 30–100 surrounded by a frothy liquid that hardens into a cream or brown protective egg case. Native plant buffers can provide alternate prey sources, as well as shelter for overwintering egg cases.

PLEASE NOTE: Purchasing commercially-available egg cases of the introduced Chinese mantid (*Tenodera sinensis*) is **NOT** recommended, because of the risks associated with introducing a non-native species to areas where it is not historically found. Chinese mantids may not provide reliable biological control because they are generalist predators that will readily consume beneficial invertebrates as well as small vertebrates like tree frogs, lizards, and hummingbirds.

Green Lacewings, Brown Lacewings [ORDER: Neuroptera; FAMILIES: Chrysopidae, Hemerobiidae]

» Green Lacewings [FAMILY: Chrysopidae]

ADULT SIZE: 15–25 mm

IDENTIFICATION: Green lacewing eggs are tiny white ovals atop thread-like silk stalks attached to foliage. The larvae of both green and brown lacewings are similar (6–10 mm long), with gray-green or brown "alligator-like" bodies and sharp, long sickle-shaped jaws. Green lacewing adults have a pale green body, with eyes that are coppery metallic in color, long thread-like antennae, and delicate, membranous wings.

SPECIES: ~90

PRIMARY HABITAT: Green lacewings are more often seen in crops, fields, and gardens.

» Brown Lacewings [FAMILY: Hemerobiidae]

ADULT SIZE: 6–12 mm

IDENTIFICATION: The pale cream or pink eggs of brown lacewings are laid on the underside of leaves, without stalks. Brown lacewings larvae are similar to green lacewings (see left), though larvae of brown lacewings are slightly more slender and are known to wag their heads from side to side. Adult brown lacewings are very similar to green lacewings, though they are smaller and are brownish in color.

SPECIES: ~60

PRIMARY HABITAT: Brown lacewings are more abundant in forests, orchards, and fields with wooded edges.

DIET: Adults and larvae are generalist predators. Lacewing larvae are especially voracious predators; they may travel up to 100' in search of prey on foliage and can consume up to 400 aphids each week, earning the nickname, "aphid lion".

COMMON PREY:

- Aphids
- Small caterpillars/ larvae
- Beetles
- Thrips
- Mites
- Whiteflies
- Mealybugs
- Other small, soft-bodied insects

FIGURE 53: Lacewing larvae are equipped with powerful, sickle-shaped jaws for piercing prey[L]. In the absence of prey, they will also consume pollen and nectar[R].

FIGURE 54: Green lacewings oviposit[TL] eggs on foliage near prey, attached with silken strands[TR]. After hatching, larvae[BR] go through several instars before pupating in a small, round cocoon[BL].

FIGURE 55: Brown lacewings[TL] oviposit tiny eggs underneath leaves near prey[TR]. After hatching, larvae[BR] go through several instars before pupating in an airy cocoon[BL].

Green Lacewings, Brown Lacewings *continued*

FIGURE 56: Green lacewing larvae sometimes carry debris—a combination of plant litter, lichen, and the remains of prey—as camouflage against predators, prey, and competitors.

FIGURE 57: Females oviposit on foliage close to prey—often near aphid colonies—to provide their offspring with food immediately after hatching.

DEVELOPMENT: ~40 days

METAMORPHOSIS: Complete—lacewings pupate inside silken cocoons attached to the undersides of leaves or in other sheltered sites (e.g., under bark).

GENERATIONS PER YEAR: Multiple

OVERWINTERING: Either as pre-pupae within cocoons attached to leaves or adults in sheltered areas such as leaf litter.

BEHAVIORIAL NOTES: Green lacewing larvae can sometimes be seen carrying debris, making them resemble whiteflies or woolly aphids. Lacewing adults are most active at night. Grown lacewings have low temperature thresholds and are active in cooler temperatures when other predators are not.

CONSERVATION STRATEGIES: In the absence of pollen and nectar provided by flowering plants, adult lacewings may not lay eggs and may disperse elsewhere in search of food. Attract and support lacewings by planting a diversity of flowers within or near to crops that have varying bloom times to provide nectar and pollen throughout the growing season. Forested windbreaks or trees near field edges may provide additional habitat. Humidity provided by dense plantings of grass may also be important for preventing desiccation of young lacewing larvae.

FIGURE 58: Lacewings can often be seen on flowers because they regularly feed on pollen and nectar in the absence of prey.

Firefly Beetles/Fireflies/Lightning Bugs [ORDER: Coleoptera; FAMILY: Lampyridae]

ADULT SIZE: 5–20 mm

IDENTIFICATION: Adult fireflies superficially resemble soldier beetles with soft, leathery wing covers, but most species can be distinguished by the light-producing segments near the end of their abdomen. Female fireflies have shorter elytra and fewer luminous segments than males, and many species are wingless. The predatory larvae have strong, sickle-like jaws, and are referred to by some as "glowworms" because they are also luminescent.

DIET: Larvae are semi-specialist predators of soft-bodied insects in soil and semi-aquatic habitats. Little is known about the diets of adults, which have been documented to feed on nectar and pollen. Note: some short-lived species do not feed as adults.

COMMON PREY:

- Snails/ slugs
- Caterpillars
- Worms
- Other small soft-bodied insects

SPECIES: ~125

DEVELOPMENT: Up to a year

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: 1–2

OVERWINTERING: Larvae overwinter under bark or in the soil.

PRIMARY HABITAT: Larvae reside in damp areas where prey is found, and under bark. Fireflies pupate in soil, under rocks, or in leaf litter.

CONSERVATION STRATEGIES: Tall grass in field edges or nearby habitat can be shelter for adults and should be protected or supplemented. Reduced tillage can protect egg-laying sites as well as larval habitat and overwintering sites. Flowers with an open structure and exposed nectaries, such as those in the sunflower family, may attract pollen- and nectar-seeking adults.

FIGURE 59: Adult fireflies resemble soldier beetles when their protective leathery outer wings ('elytra') are closed. Among flying species, their hindwings are only visible in flight.

FIGURE 60: Firefly larvae—similar to lacewing larvae—have strong, sickle-shaped jaws for catching prey[L] (inset) and an alligator-like body[R].

FIGURE 61: Luminescent firefly species[L] are not found west of Kansas. In the west, there are 19 species of diurnal fireflies (GENERA: *Ellychnia*[R], *Lucidota*, *Pyropyga*) that do not produce light as adults because they are mostly active during the day.

Ground Beetles, Tiger Beetles [ORDER: Coleoptera; FAMILY: Carabidae]

» Ground Beetles

ADULT SIZE: 1–60 mm

IDENTIFICATION: Larvae are cream to brown in color, with a round head with hooked jaws, long legs, and bristly posterior projections. Adult ground beetles range in size from small to large, and have threadlike antennae, prominent eyes, a head narrower than their thorax, an extended-oval abdomen, and ridged wing covers. Their coloration is dark and shiny, usually black or brown, with green, blue, or purple iridescence in some species. Ground beetle eggs are usually found in the top layer of moist soil, inside crevices, or under debris.

» Tiger Beetles [SUBFAMILY: Cicindelinae]

ADULT SIZE: 7–70 mm

IDENTIFICATION: Rarely seen, tiger beetle larvae hatch from eggs laid in burrows that they enlarge as they grow. The larvae use hooks on their abdomen to anchor themselves into their burrow, and catch prey that wanders within reach. Adults vary in coloration from gray-brown to metallic bronze and irridescent jewel tones, sometimes with markings on their wing covers. Their long, thin legs are used to dash in short, quick bursts. They have long sickle-shaped jaws to capture and chew prey. Tiger beetles prefer hunting on open ground where they can sprint.

DIET: Most members of the family Carabidae are generalist predators. Both larvae and adults can eat their body weight in prey each day. While most ground beetles are nocturnal, many tiger beetles are active during the day. Adults tend to hunt on the soil surface or on vegetation, while larvae hunt for rootworms, caterpillars, and other soft-bodied insects under the soil surface. Larvae are known to kill more prey than they can eat.

COMMON PREY:

- Small insects
- Larvae*/ small caterpillars (*fly and beetle; e.g., Colorado potato beetle)
- Caterpillars (e.g., gypsy moths, tent caterpillars)
- Aphids
- Snails/ slugs

FIGURE 62: Ground beetles target a variety of insects. Larvae[T] and adults[B] in the genus *Dicaelus* are known for hunting snails.

FIGURE 63: Tiger beetles prefer open ground and sandy soil where larvae[TL] hunt from burrows[TR] and adults[B] chase down prey.

Ground Beetles, Tiger Beetles *continued*

SPECIES: 3000+ (combined)

DEVELOPMENT: One year, with adults living up to four years

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: 1

OVERWINTERING: Grass clumps as larvae or adults

PRIMARY HABITAT: Under debris, logs, in soil cracks, or moving along the ground or on vegetation

CONSERVATION STRATEGIES: Create permanent plantings near crops to support ground beetles. Beetle banks can provide important overwintering habitat for ground beetles. In wheat plantings, farmers have found that the cost of building beetle banks can be offset by the savings resulting from reduced need for pesticide use. Mulched areas can also be a refuge, but avoid excessive tillage or burning of crop residue, as these practices can impact multiple life stages of these beetles and can reduce populations quickly. Research also suggests that animal manure and composts benefits the beetles over chemical fertilizer. Weed seed predators are more often found in fields with surface residue rather than bare fallow fields.

FIGURE 64: Ground and tiger beetles often hide around logs or rocks during the day, where they can stay cool and moist. This six-spotted tiger beetle (*Cicindela sexguttata*) was found inside a log.

FIGURE 65: Left to right: different species of ground beetles flourish in native buffer plantings on various Minnesota organic farms, where mulch and surface residue provide places under which beetles can hide.

Lady Beetles/Ladybugs/Ladybird Beetles [ORDER: Coleoptera; FAMILY: Coccinellidae]

ADULT SIZE: 1–8 mm

IDENTIFICATION: Lady beetle eggs are elliptical, yellow-orange in color, and are usually laid in clusters on leaves and stems near prey. Larvae have an elongated, flattened, alligator-like body, and typically dark coloration with bright bands or spots. Adult lady beetles are small to medium in size, with oval, convex bodies. They are often brightly colored with dark markings or black or beige with red or yellow markings.

DIET: Semi-specialist predators—most lady beetle larvae and adults are specialist predators of aphids or scales, but some species will also consume other pests in the absence of their preferred prey. A single lady beetle may consume up to 5,000 aphids in its lifetime.

PREFERRED PREY:
- Aphids
- Scales/ mealybugs

ALTERNATE PREY:
- Whiteflies
- Mites
- Thrips
- Insect eggs

SPECIES: ~475

DEVELOPMENT: ~45 days

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: 1–3

OVERWINTERING: Protected locations, such as leaf litter, in rock crevices, behind bark, or in the eaves of homes

PRIMARY HABITAT: Vegetation in agricultural fields, natural areas, and gardens.

CONSERVATION STRATEGIES: Noncropped areas or plantings within fields that support plants producing pollen and nectar at varying times of the growing season can provide adult lady beetles and larvae with valuable nonprey food. Flowers that are shallow or open in shape, such as flowers in the sunflower or carrot families, may be most attractive to lady beetles due to the accessibility of floral resources. Areas with tall or dense grass can provide a welcome humid microclimate for beetles in the summer and be potential overwintering sites. Several species of lady beetles have been introduced into the United States for classical biological control. Some of these species, such as the multicolored Asian lady beetle (*Harmonia axyridis*) and the seven-spotted lady beetle (*Coccinella septempunctata*), may be outcompeting and displacing native species (see opposite page).

FIGURE 66: Clockwise from top left: lady beetles lay tiny bright yellow eggs on leaves, stems, or buds. After hatching, the alligator-like larvae are usually dark with bright spots or stripes.

FIGURE 67: Convergent lady beetles (*Hippodamia convergens*) overwinter in groups in protected locations, such as under leaf litter (inset) or in dense clusters of bunchgrass.

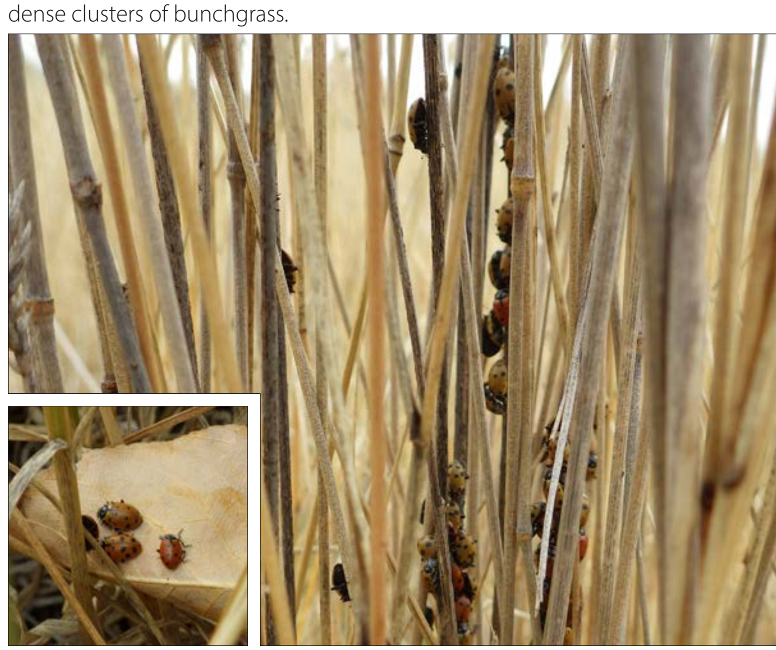
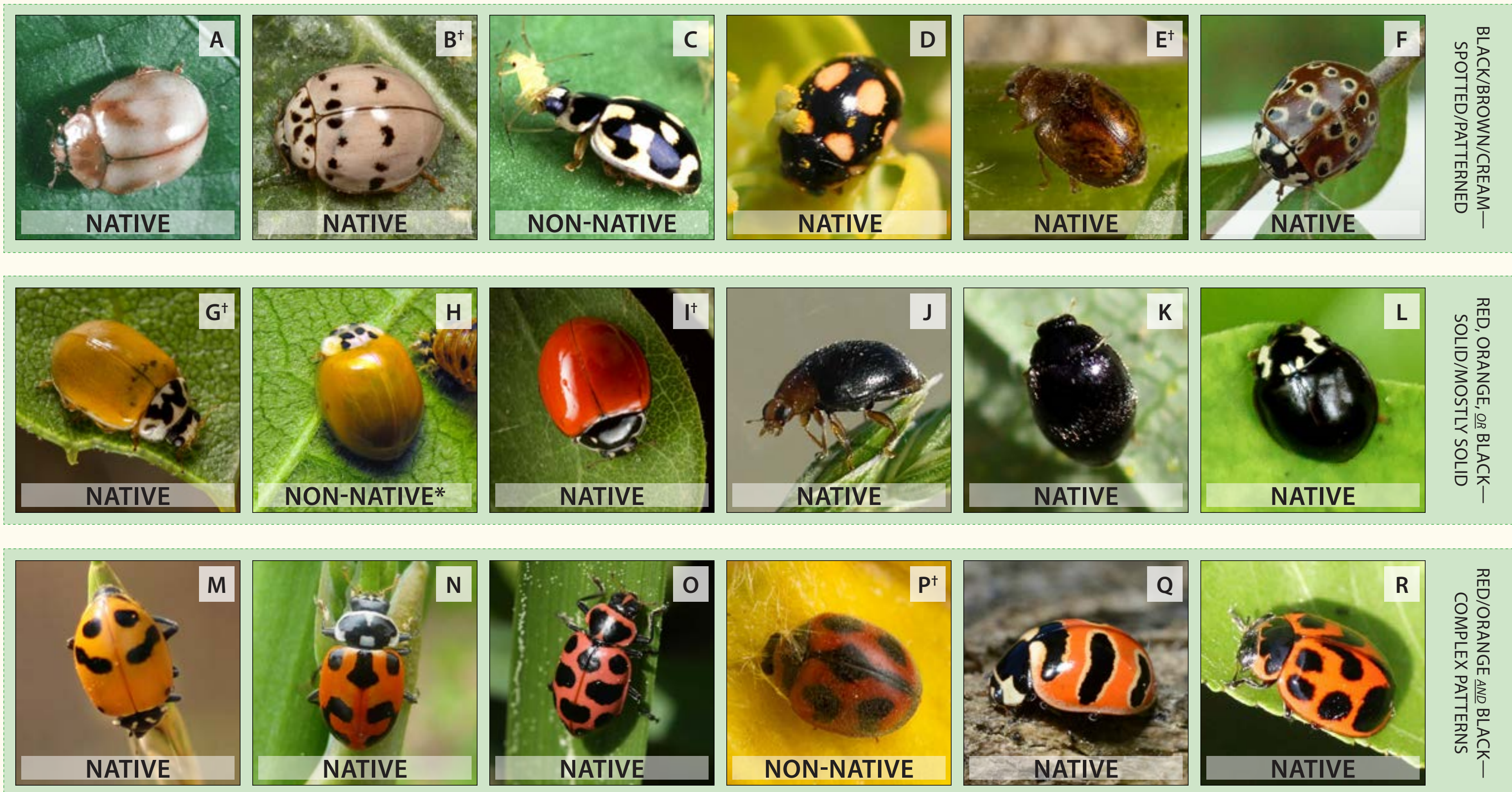


Figure 68: Many of the 400+ lady beetle species found in North America don't look like the familiar red beetle with black spots. They range from solid black ~1.5-mm-long mealybug hunters (*Stethorus* spp.[K]) to ≤10.5 mm giant lady beetles (*Anatis* spp.[F,L]) that hunt aphids and caterpillars on trees. The species included below are widely distributed in different regions across North America, though some may be rare within their native range or currently in decline. For more information about identifying and monitoring native lady beetles, visit the Lost Lady Beetle Project (www.lostladybug.org).



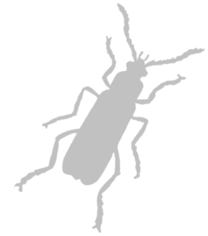
Species:

A. Cream-spotted lady beetle (*Calvia quatuordecimguttata*)
B. Ashy gray lady beetle (*Olla v-nigrum*)† (+ alternate dark form)
C. Fourteen-spotted lady beetle (*Propylea quatuordecimpunctata*)
D. *Hyperaspis* spp.
E. Nebulous lady beetle (*Scymnus nebulosus*)†
F. Eye-spotted lady beetle (*Anatis mali*)
G. Painted lady beetle (*Mulsantina picta*)†
H. Multicolored Asian lady beetle (*Harmonia axyridis*)*
I. Spotless lady beetle (*Cycloneda sanguinea*)†
J. Kansas lady beetle (*Scymnus kansanus*)
K. *Stethorus* spp.
L. Fifteen-spotted lady beetle (*Anatis labiculata*)
M. Glacial lady beetle (*Hippodamia glacialis*)†
N. Parenthesis lady beetle (*Hippodamia parenthesis*)
O. Spotted lady beetle (*Coleomegilla maculata*)
P. Vedalia lady beetle (*Rodolia cardinalis*)†
Q. Three-banded lady beetle (*Coccinella trifasciata*)
R. V-marked lady beetle (*Neoharmonia venusta*)
S. Two-spotted lady beetle (*Adalia bipunctata*)
T. Twice-stabbed lady beetle (*Chilocorus stigma*)
U. Seven-spotted lady beetle (*Coccinella septempunctata*)
V. Nine-spotted lady beetle (*Coccinella novemnotata*)
W. Eleven-spotted lady beetle (*Coccinella undecimpunctata*)
X. Thirteen-spotted lady beetle (*Hippodamia tredecimpunctata*)
Y. Convergent lady beetle (*Hippodamia convergens*)
Z. Multicolored Asian lady beetles (*H. axyridis*)*

Notes:

* *The introduced multicolored Asian lady beetle[H,Z] is highly variable in appearance. It can be found across North America with 0–22 spots and mixed yellow-orange, orange, red, or black coloration, and is easy to confuse with such species as the the two-spotted lady beetle[S], the dark form of the ashy gray lady beetle[B], and the twice-stabbed lady beetle[T].*

† Photographs[B,E,G,I,P] © Alice Abela



Soldier Beetles [ORDER: Coleoptera; FAMILY: Cantharidae]

FIGURE 69: Soldier beetle larvae are long and dark with dense bristles that give them a velvety appearance. They are generalist predators of soft-bodied insects—such as caterpillars.

FIGURE 70: Soldier beetles are particularly attracted to flowers with easily-accessible pollen and nectar, such as prairie coneflower (*Ratibida pinnata*), a member of the sunflower family.

ADULT SIZE: 1–18 mm

IDENTIFICATION: Adult soldier beetles are soft-bodied with elongated abdomens and leathery wing covers, often resembling fireflies with their black, brown, yellow, or orange coloration—minus the light producing segments. Their eggs are laid in moist soil or leaf litter. The dark, flattened larvae hunt for other insects in loose soil, leaf litter, under rocks or debris, or under bark, and some are known to be active hunters even during cold weather.

DIET: Generalist predators

COMMON PREY:

- Insect eggs
- Caterpillars
- Various insect larvae and worms
- Aphids
- Other small soft-bodied insects
- Snails/ slugs

SPECIES: ~470

DEVELOPMENT: About a year

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: 1–2

OVERWINTERING: Larvae overwinter in leaf litter.

PRIMARY HABITAT: Pupation occurs just below the soil surface

CONSERVATION STRATEGIES: Adults of these beetles need pollen and nectar to survive, and appear to prefer flowers with open structure and accessible pollen and nectar, such as those in the sunflower and carrot families. They are also common on other floral species with clusters of small flowers, such as milkweeds. Protect or supplement habitat near or within fields to support pollen and nectar sources. Protect egg-laying sites as well as larval habitat and overwintering sites in fields by avoiding soil fumigants and insecticides, and reducing tillage. There is some evidence to suggest that larvae prefer areas with higher plant cover and humidity over bare ground, so areas of constant plant cover, such as cover crops or permanent plantings, may benefit larvae and their migration into nearby crops.

Rove Beetles [ORDER: Coleoptera; FAMILY: Staphylinidae]

ADULT SIZE: 1–25 mm

IDENTIFICATION: Rove beetle arvae have a square head, elongated body, and are light to dark brown in color. Adults are black or brown in color with elongated, slender bodies and short wing covers. Adults vary in size from 1–25 mm, depending on the species. Rove beetles are quick runners and flyers, and many curl the tip of their abdomen slightly upwards as they run or when disturbed by potential predators.

DIET: Generalist predators of pests in soil

COMMON PREY:

- Insect eggs
- Small insect larvae
- Fungus gnats (e.g., Sciaridae)
- Flies
- Mites
- Thrips (e.g., *Frankliniella occidentalis*)
- Root mealybugs
- Other small soft-bodied insects (e.g., springtails)
- Snails & slugs

SPECIES: 3,000+

DEVELOPMENT: 20 days to a year

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: One to multiple (varies with species)

OVERWINTERING: Under bark or vegetation as larvae, pupae, or adults

PRIMARY HABITAT: Eggs are laid on leaves or under debris, and both larvae and adults are found in soils, mulch, leaf litter, or on vegetation.

CONSERVATION STRATEGIES: Rove beetles may benefit from beetle banks. Researchers have found that species diversity and abundance of rove beetles increased with the age of wildflower field borders. Limit tillage and soil fumigants, which alter both larval and adult habitat. Rove beetles will use mulch, litter, compost piles, or rock piles for overwintering habitat. Staggering harvest times of perennial field crops may help these beetles to remain in fields rather than migrate elsewhere.

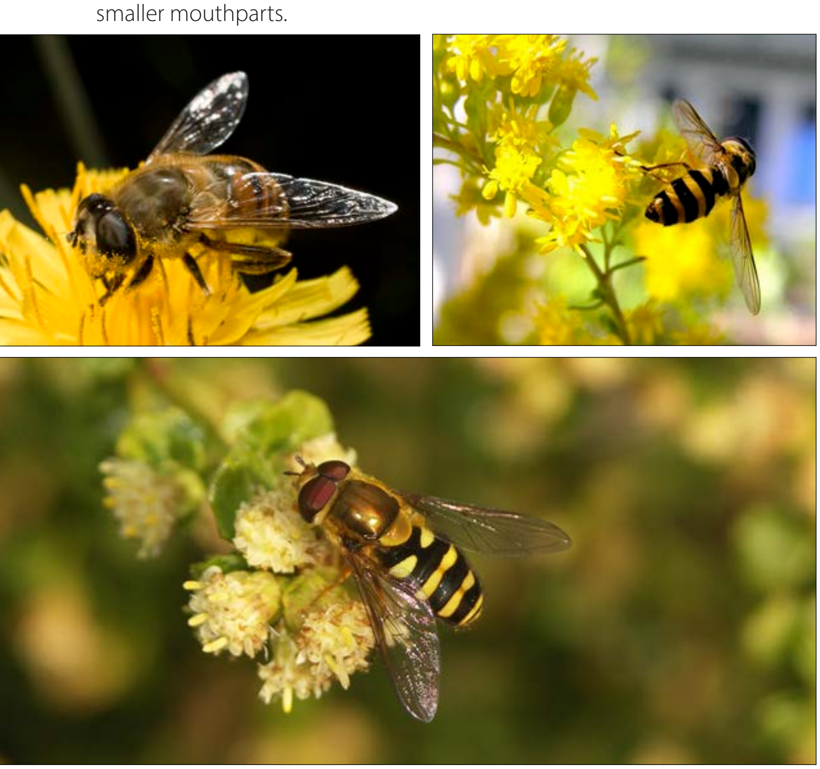
FIGURE 71: Rove beetle larvae and adults are frequently brown or black in coloration and and be difficult to spot due to their quick speed on land or in flight.

FIGURE 72: The brown rove beetle (*Platydracus maculosus*) is a common species that is found in rotting vegetation and around dung, where it feeds on various insects, including adult flies and fly larvae.

Flower Flies/Hoverflies/Syrphid Flies [ORDER: Diptera; FAMILY: Syrphidae]

FIGURE 73: Flower fly eggs are usually found near prey[TL] (circled in blue), where larvae (shown: *Epistrophe* sp.) can easily hunt for prey by waving their heads from side to side[TR] . Flower fly larvae come in many colors, including bright green[BR] to mottled brown-gray-green[BM] or orange[BL].

FIGURE 74: Many flower fly species are often mistaken for bees or wasps[TL], but, unlike bees, they can only visit shallow, open flowers—like goldenrod (*Solidago* spp.)[TR] and coyotebush (*Baccharis pilularis* spp.)[B]—due to their smaller mouthparts.



ADULT SIZE: 8–20 mm

IDENTIFICATION: Flower fly eggs are tiny (1 mm) cream-colored ovals laid on foliage close to prey (e.g., next to an aphid colony). These develop into legless larvae, some of which bear distinctive markings, stripes, or spines. Larvae swing their head from side to side while hunting prey in leaf litter or on foliage. Adult flies have two wings, short stout antennae, and large broad eyes. Adults often have bright coloration and many species mimic bees or wasps, some to a striking degree.

DIET: Flower fly larvae are generalist predators that frequently target aphids, and have been known to consume as many as 50 aphids per day. They are particularly important in controlling aphid infestations early in the season, when cooler temperatures may inhibit other predators. Adults consume nectar and pollen, and can be important pollinators.

COMMON PREY:

- Aphids
- Scales/ mealybugs
- Spider mites
- Thrips

SPECIES: ~900

DEVELOPMENT: 4–10 weeks

GENERATIONS PER YEAR: One to multiple (varies with species)

METAMORPHOSIS: Complete

OVERWINTERING: In leaf litter or in the soil as larvae, pupae, or adults

PRIMARY HABITAT: Adults can be found in habitats with abundant flowering plants.

CONSERVATION STRATEGIES: Protect grasslands, rangelands, meadows, gardens, field borders, hedgerows, and plantings within crop fields. When planted or managed to provide a continuous bloom of flowering plants, these areas can support large flower fly populations. Shallow, open flowers (such as plants in the willow, rose, buttercup, sunflower, and carrot families) may be especially attractive to flower flies. Since flower flies are less active under windy conditions, windbreaks may provide shelter and increase populations. Tilling and burning, which may destroy overwintering sites, should be limited.

Predatory Wasps [ORDER: Hymenoptera; FAMILIES: Vespidae, Sphecidae]

These wasps build nests where their young develop. While all sphecid wasps are solitary, with each individual female constructing and provisioning her nest, some vespids are social, forming colonies with a queen, and a division of labor among female workers.

» Paper Wasps [FAMILY: Vespidae]

ADULT SIZE: 10–25 mm

IDENTIFICATION: Adult vespid wasps have a notch along the inner margin of their eyes, a thin waist, and are black or brown with white, yellow, red, or orange markings. Vespid wasps fold their wings in half when at rest, and at a glance they appear to have only one thin pair of wings.

SPECIES: ~320

» Thread-waisted & Sand Wasps [FAMILY: Sphecidae]

ADULT SIZE: 10–30 mm

IDENTIFICATION: Adult sphecid wasps are fully black, slightly metallic, or black with red, yellow, or white markings. Sphecid wasps tend to be more slender than vespids—the aptly named thread-waisted wasps have a very thin, elongated waist—and do not have notched eyes.

SPECIES: ~1,150

DIET: Some species are generalists, while others may hunt more selectively on particular pest groups. Adult females collect prey to bring back to their nests as food for their carnivorous larvae.

GENERALIST PREY:
- Caterpillars
- Beetles (larvae and adults)
- Flies (larvae and adults)
- True bugs (nymphs and adults)

SEMI-SPECIALIST PREY:
- Grasshoppers
- Caterpillars
- Aphids

DEVELOPMENT: ~40 days to a year (varies with species)

METAMORPHOSIS: Complete

FIGURE 75: Thread-waisted wasps paralyze prey to bring back to their nests—members of the genus *Ammophila* (shown) specialize in caterpillars and sawflies.

FIGURE 76: Paper wasps (*Polistes* spp.) and other vespids collect various insects to bring back to the nest. Many specialize in pest caterpillars, like this native species collecting tobacco hornworm (*Manduca sexta*) larvae.

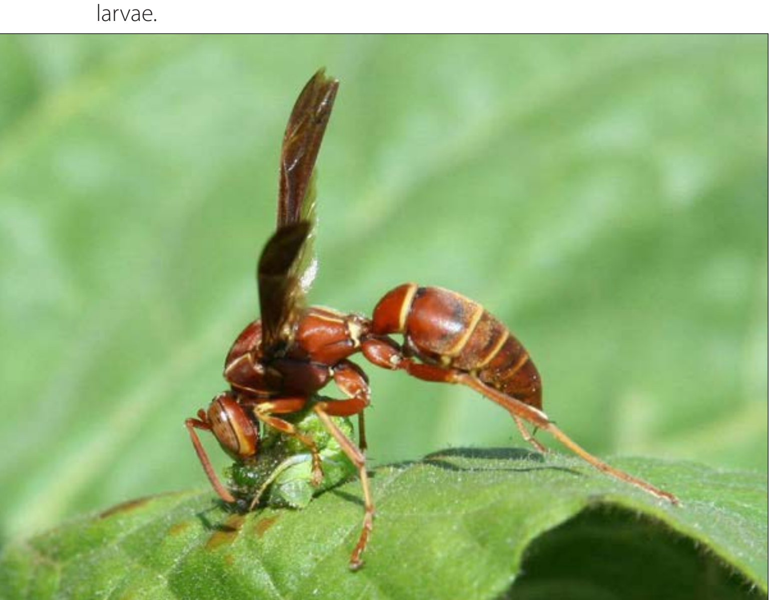


FIGURE 77: Sand wasps (TRIBE: Bembicini) are solitary, ground-nesting wasps[L] that were traditionally classified as sphecids. The species *Bicyrtes quadrifasciatus* specializes in true bugs—such as stink bugs[R] (shown: *Banasa sordida*).

Predatory Wasps *continued*

Figure 78: Relatives of social vespids, soiltary potter wasps (subfamily: Eumeninae; shown: *Eumenes fraternus*) construct individual brood cells from clay and sand that resemble small pots. Each miniature nest is provisioned with caterpillars and beetle larvae.

Figure 79: Adult predatory wasps rely on flowers with shallow nectaries, such as dotted mint (*Monarda punctata*), a member of the mint family that attracts various beneficial insect species.

GENERATIONS PER YEAR: One to several (varies with species)

OVERWINTERING: Within nest (solitary or communal, in the soil, in cavities, in wood) as prepupae or adults

PRIMARY HABITAT: These wasps build nests in which their young develop. While all sphecid wasps are solitary, with each individual female constructing and provisioning her nest, some vespids are truly social, forming colonies with a queen, and a division of labor among female workers. Social vespids construct paper nests made from wood chewed to pulp and feed masticated prey to their young. Social vespids can be aggressive, particularly the yellow jackets, and in the eyes of landowners the disadvantage of these colonies on farms may outweigh the benefits. Paper wasps, however, are less aggressive and excellent caterpillar hunters, and may be worth encouraging on farms. Solitary vespids construct cells out of clay or chewed foliage on twigs of trees, stems, crevices of walls, or between rocks. Many solitary sphecid wasps will build nests in cavities or in the ground, and may utilize pieces of grass, mud, or resin in construction of their nest.

CONSERVATION STRATEGIES: Adult predatory wasps drink nectar from shallow flowers such as milkweeds and members of the sunflower, carrot, and mint families.

ARTIFICIAL NESTING HABITAT: Some species of solitary wasps will readily utilize artificial nesting boxes, such as those used to attract solitary bees. For more information about construction and management of artificial nests, please see the Xerces Society's fact sheet, *Tunnel Nest Construction and Management* (available at: www.xerces.org/wp-content/uploads/2009/11/tunnel-nest-management-xerces-society.pdf). Three-sided wooden shelters with a roof and an open bottom erected on posts around tobacco fields were shown to encourage nesting by paper wasps (and reduce pest caterpillars).

Tachinid Flies [ORDER: Diptera; FAMILY: Tachinidae]

ADULT SIZE: 5–20 mm

IDENTIFICATION: Adults of tachinid flies vary in size, and resemble a house fly in general appearance, but with stiff bristles on the abdomen. Coloration varies widely, although many are gray or brown in color with dark bristles; others have vivid yellow or red markings or are metallic blue or green. Most species of tachinid flies attack the larval stage of their host, usually by laying their eggs either near or directly on their host. Several species also use a sharp ovipositor to insert eggs into the host's body). The developing fly consumes the host and pupates around the time the host dies.

TARGET HOSTS: Larval stages of certain pest groups, while others attack a variety of arthropod hosts.

COMMON HOSTS:

- Caterpillars (various Lepidoptera species)
- Beetle & sawfly larvae
- True bugs (e.g., stink bugs, squash bugs, etc.)
- Grasshoppers
- Other adult arthropods

SPECIES: 1000+

DEVELOPMENT: Varies with species, but can be less than four weeks

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: Multiple

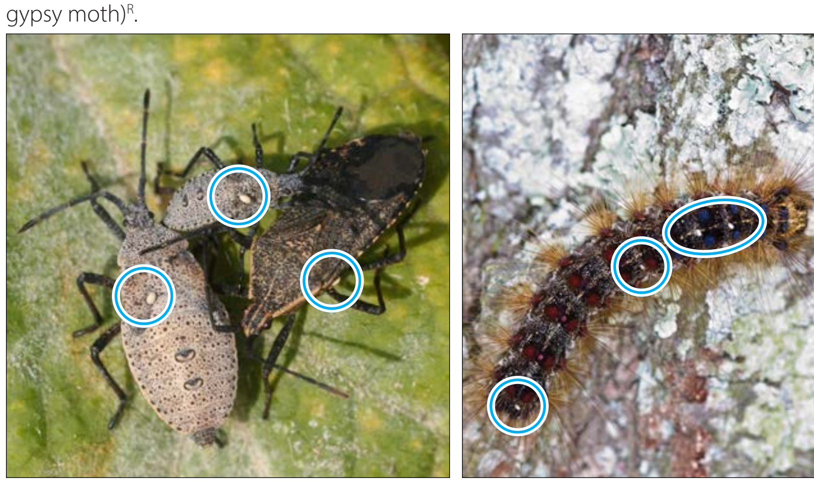
OVERWINTERING: As larvae or pupae within their host

PRIMARY HABITAT: Some species will pupate in leaf litter (others pupate within their host); adults can be found on flowers

CONSERVATION STRATEGIES: To support tachinids, maintain consecutively blooming wildflowers for a steady supply of nectar as an adult food source. Flowers with easily accessible nectar are best. Plants from the carrot, sunflower, rose, willow, mint, and milkweed families may be particularly attractive to these flies. Tachinids are more abundant in less disturbed field margins, and two or more years may be required for their populations to recover following a habitat disturbance.

FIGURE 80: Many tachinid species (shown: *Paradidyma singularis* on milkweed)[T], resemble house flies; whereas, others—like the feather-legged fly (*Trichopoda pennipes*)[B], shown on goldenrod—can have vivid yellow or orange coloration.

FIGURE 81: Tachinid flies lay eggs (outlined in blue) on or in numerous pest groups, including true bugs (shown: squash bugs)[L] and caterpillars (shown: gypsy moth)[R].



PARASITOIDS

Parasitoid Wasps [ORDER: Hymenoptera; SUB-ORDER: Parasitica; SUPERFAMILIES: Ichneumonoidea, Chalcidoidea]

As adult wasps, some species are extremely tiny (<5 mm) while others are more sizable (up to 20 mm). These wasps all have slender bodies with narrow waists (although this may be hard to see). Females have an ovipositor—a long, stinger-like appendage used to deposit eggs into hosts—though it is less visible in some species. The life cycle of parasitoid wasps is closely synchronized to that of their hosts.

An adult female wasp finds a host at the appropriate life stage and deposits one or several eggs on, inside, or near the host. The larvae develop on or inside the host, feeding on it, but usually not killing the host until the wasp larvae reach maturity and pupate. Adult wasps emerge and seek out new hosts to repeat the cycle.

» Ichneumonoidea [FAMILIES: Ichneumonidae, Braconidae]

ADULT SIZE: 1–40 mm

IDENTIFICATION: Larger parasitoid wasps in the superfamily Ichneumonoidea (includes the families Ichneumonidae and Braconidae) have dark coloration with red, orange, or yellow markings and long, threadlike antennae.

SPECIES: 5,000+ species in the superfamily Ichneumonidea

» Chalcidoidea [FAMILIES: Aphelinidae, Chalcididae, etc.]

ADULT SIZE: 0.1–20 mm

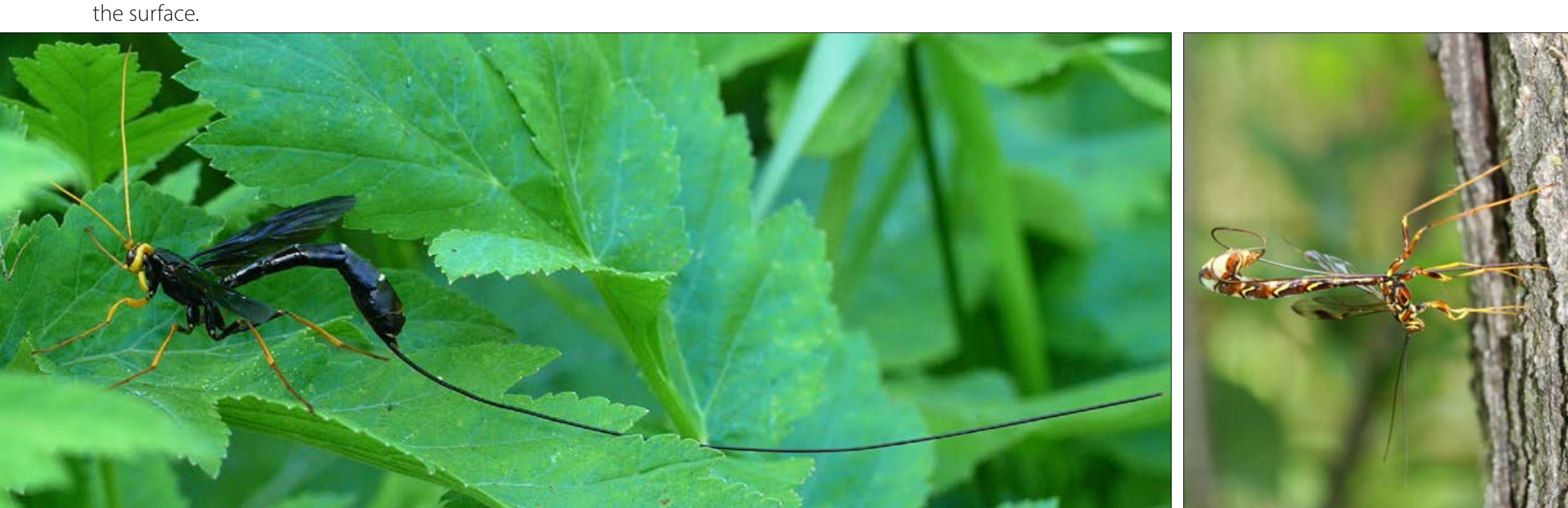
IDENTIFICATION: Tiny parasitoid wasps in the superfamily Chalcidoidea (includes families such as Aphelinidae, Trichogrammatidae, Encyrtidae, and Chalcididae) are black, dark blue, or green, and often metallic in color.

SPECIES: 2,600+ species in the superfamily Chalcidoidea

FIGURE 82: Many braconid species are predominantly dark-colored with bright markings, such as this female (males do not possess ovipositors) feeding on lovage.

FIGURE 83: *Torymus* spp. (SUPERFAMILY: Chalcidoidea) are parasitoids of gall-forming insects and numerous species are being used for biological control around the world.

FIGURE 84: While ichneumonid wasps may seem terrifying because of their long ovipositors, they actually pose no threat to humans. Female giant ichneumons (*Megarhyssa* spp.) possess ovipositors that can measure over 100 mm[L], which they use to parasitize wood-boring insects[R] up to 14 cm under the surface.



Parasitoid Wasps *continued*

TARGET HOSTS: Many parasitoid wasps are host-specific and are highly effective in regulating the populations of particular pests. Hosts include the eggs, larvae, and adults of numerous pest groups, like aphids and beetles.

COMMON HOSTS ***include*** **eggs, larvae, *or* adults *of:***

- Aphids
- Whiteflies
- Scales/ mealybugs
- Caterpillars
- Flies
- Beetles
- Leafhoppers
- Many other insects

DEVELOPMENT: Varies with species/host

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: Numerous overlapping generations

OVERWINTERING: As an egg or larva within their host, as a pupa within their cocoon, or as adults

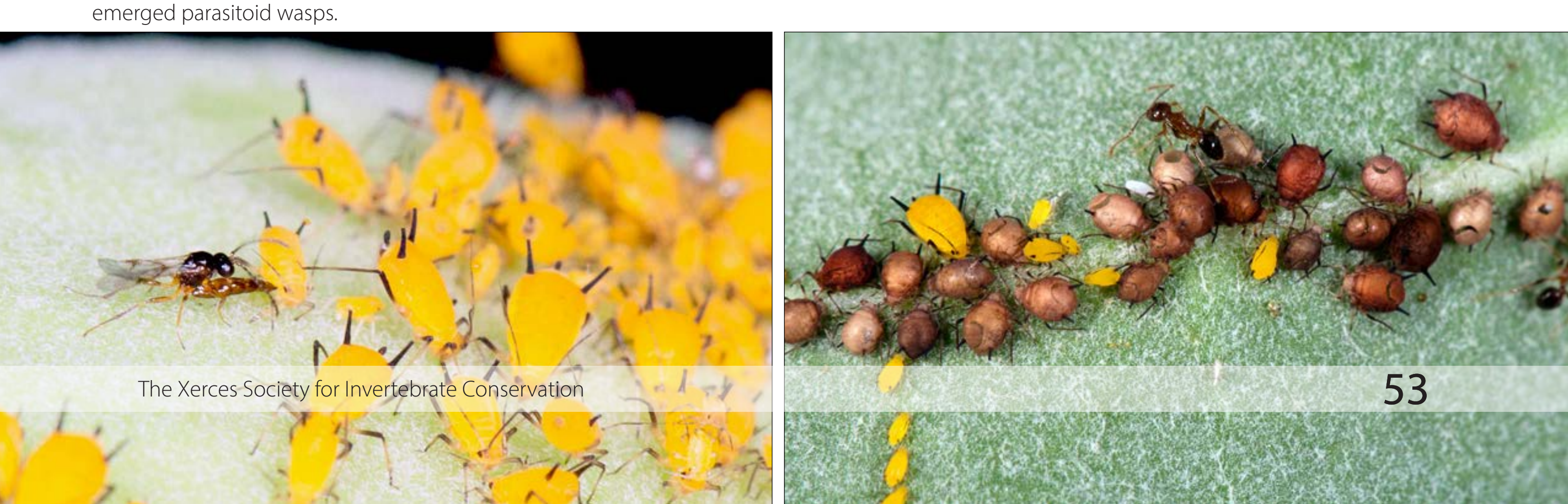
PRIMARY HABITAT: Adults can be found on flowers with shallow nectar reserves.

CONSERVATION STRATEGIES: Wooded edges near fields, in combination with nectar sources, increase the abundance of parasitoids and levels of parasitism. Permanent plantings with a succession of flowering plants that bloom throughout the season, including species in the carrot, bean, sunflower, and mint families, will support adult parasitic wasps and increase their longevity and reproduction. Increasing crop diversity can also increase parasitic wasp populations on farms.

FIGURE 85: Wasps in the family Mymaridae (SUPERFAMILY: Chalcidoidea) are generalist egg parasitoids and among smallest insects in the world—many measuring less than 1 mm—such as this "fairyfly" waiting for a female weevil to lay eggs after mating.

FIGURE 86: Braconid wasp foraging on seaside daisy (*Erigeron glaucus*), a wildflower with shallow nectar reserves.

FIGURE 87: Tiny Aphidiinae wasps (FAMILY: Braconidae) are aphid specialists that measure around 2.5 mm long—frequently smaller than their hosts[L]—that can be highly effective control agents against aphid colonies, as demonstrated by the papery aphid "mummies"[R] that indicate the number of recently emerged parasitoid wasps.



Parasitoid Wasps [ORDER: Hymenoptera; SUB-ORDER: Aculeata]

» Scarab-Hunting Parasitoid Wasps [SUPERFAMILY: Vespoidea]

»» Scoliid Wasps [FAMILY: Scoliidae]

ADULT SIZE: 20–50 mm

IDENTIFICATION: Adult scoliids are large (20–50 mm), robust wasps that are very hairy. Their bodies are often very black with bright orange, yellow, or red colorations, and their wings are darkened.

SPECIES: 20+

»» Tiphiid Wasps [FAMILY: Tiphiidae]

ADULT SIZE: 1–20 mm

IDENTIFICATION: Tiphiid wasps are smaller (usually less than 20 mm in length) and less hairy than scoliid wasps, and most have yellow and black coloration.

SPECIES: 140+

TARGET HOSTS: These wasp larvae are specialist parasitoids of subterranean beetle larvae.

MOST COMMON LARVAL HOSTS*:*

- Scarab, stag, and bess beetles (Scarabaeoidea)
- Darkling beetles (Tenebrionidae)
- Tiger beetles (Cicindelinae)

DEVELOPMENT: 10–12 months between egg deposition and emergence of adult

METAMORPHOSIS: Complete

GENERATIONS PER YEAR: 1

OVERWINTERING: Pupa overwinter in the soil

PRIMARY HABITAT: Flowering plants are needed as adults of both families drink nectar and some scoliids will consume pollen. Eggs are laid next to paralyzed prey.

CONSERVATION STRATEGIES: Field borders or permanent plantings with plenty of summer to fall blooming species can provide adult wasps with the nectar they need to survive and reproduce.

FIGURE 88: Scoliidae are large wasps that frequently have striking coloration[TL] and bold stripes[TR], often accented by dense bands of hair. They are attracted to a variety of plant species like milkweed[TL] and goldenrod[TR]. Adult females may occassionally be seen hunting for beetle or scarab larvae[B] under the soil, which they paralyze and then bury with an egg.

FIGURE 89: Tiphiid wasps exhibit strong sexual dimorphism—males[TL] have an additional abdominal segment with an upward-curved hook at the tip. The five-banded tiphiid wasp (*Myzinum quinquecinctum*)[TL,TR,B] is a widespread species that visits nectar-rich flowers like mountain mint (*Pycnathemum* spp.)[TR] and boneset (*Eupatorium* spp.)[B].

Spiders [ORDER: Araneae; FAMILIES: Lycosidae, Salticidae, Araneidae, Linyphiidae]

Spiders have four pairs of walking legs and two body regions known as the cephalothorax (the head and thorax combined) and abdomen. Silk-spinning organs are found at the posterior end of the abdomen. The body of sheet-weaving, orb-weaver, jumping, and wolf spiders can be 2–30 mm in length.

» Wolf Spiders [SUBFAMILY: Lycosidae]

ADULT SIZE: 2–35 mm

IDENTIFICATION: Wolf spiders are brown, black, or dirty yellow coloration, often with one or more longitudinal stripes on their back.

SPECIES: 240

» Jumping Spiders [SUBFAMILY: Salticidae]

ADULT SIZE: 1–22 mm

IDENTIFICATION: Jumping spiders have a fuzzy appearance with variable coloration, usually dark with iridescent patterns, and a unique eye pattern.

SPECIES: 315

» Orb Weaver Spiders [SUBFAMILY: Araneidae]

ADULT SIZE: 6–25 mm

IDENTIFICATION: Orb weavers (also called as "garden spiders") tend to be dark, with bright patterns of yellow, green, or red. Their webs are large vertical spiral webs—some can be over three feet in diameter—suspended between vegetation, usually near bushes and tall grasses.

SPECIES: 160

» Sheet-Weaving Spiders [SUBFAMILY: Linyphiidae]

ADULT SIZE: <5 mm

IDENTIFICATION: Sheet-weaving spiders are small, dark brown or black spiders that make semihorizontal webs that form a small sheet between vegetation. Sheet-weaving spiders can disperse long distances and colonize new crop fields by ballooning, using their silk threads to be carried by wind.

SPECIES: several hundred

FIGURE 90: Wolf spiders are large, active predators that chase down their prey at ground level or on plants.

FIGURE 91: Iridescent jumping spiders can frequently be seen with fresh-caught prey on plants.

FIGURE 92: Orb weavers build impressive webs, sometimes with a central zig-zag pattern or with the traditional spoked constuction, and often catch more prey than they can consume.

FIGURE 93: Sheet-weaving spiders are very small, with a long abdomen that is usually patterned. In addition to creating flat webs, Linyphiidae will make domed or bowl-shaped webs.

Spiders *continued*

DIET: Spider communities can be important in agricultural settings because they are often the most abundant and diverse predators in crop fields. Web-building spiders can help limit pest outbreaks because they catch more than they can consume. However, they are generalist predators and may feed indiscriminately on other insects, including beneficial species.

COMMON PREY: *(all families)*

- Beetles
- Caterpillars
- Leafhoppers
- Aphids
- Bees
- Wasps
- Butterflies & moths
- Various other insects (including beneficials)

SPECIES: There are approximately 3,500 species of spiders found in North America. While many families of spiders can be found in crop settings, wolf, jumping, sheet-weaving, and orb weaver spiders are some of the most common and important groups.

DEVELOPMENT: One year, but adults can live for 2–3 years

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 1

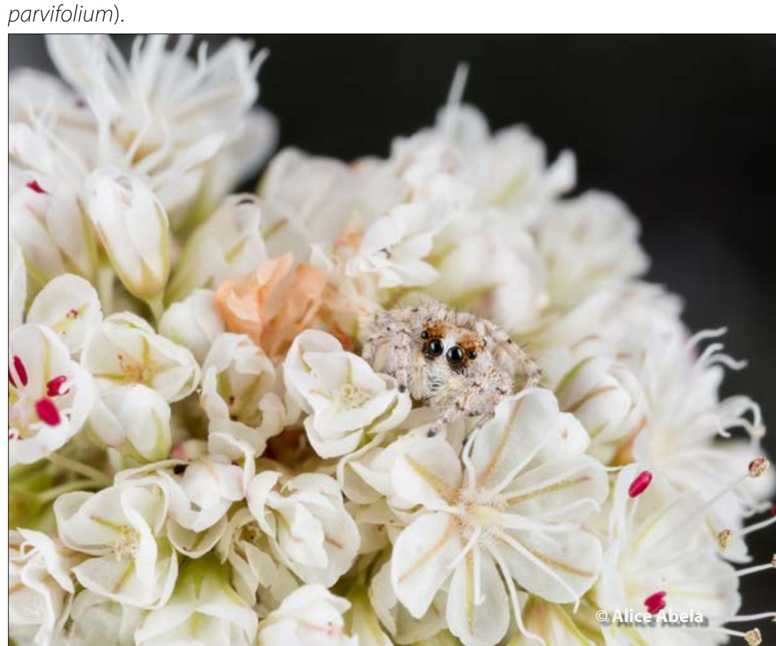
OVERWINTERING: Adults or eggs overwinter in silken nests in the soil, grass clumps, plant debris, under bark, or inside hollow stalks of vegetation.

PRIMARY HABITAT: Spiders will live anywhere with abundant prey, including forests, grasslands, urban settings, riparian areas, and in farm systems, where they live in the crop canopy or on the soil surface. Habitat structure is important for spiders, particularly orb weaver or sheet-weaving spiders which construct webs to ensnare prey. Others, such as wolf spiders and jumping spiders, actively pursue prey on the ground or on plant foliage. Spider eggs may be laid within silken sacs in leaf litter, attached to the web, or attached the body of their mothers.

CONSERVATION STRATEGIES: Spider populations can be disrupted by planting and harvesting of crops, but they can recolonize fields if suitable habitats, such as natural areas or permanently planted field borders are nearby. Field borders or hedgerows can provide spiders with shelter, as can fields or orchards with ground covers or crop residue. Maintaining cover crops, alternating harvesting of perennial field crops, and leaving residue from barley or rye crops can support spiders. Minimum tillage practices and leaving stubble between planting seasons will provide shelter and may increase the diversity of ground hunting spiders. Recent evidence suggests that a few spiders may consume some nectar, so blooming flowers may be more important to spiders than previously thought. In experimental gardens, the inclusion of mulch and flowering plants increased spider abundance and decreased damage by pests.

FIGURE 94: Female wolf spiders are notable mothers. After laying eggs, a female will wrap them in silk and carry the eggsac attached to her abdomen (left) until her offspring hatch. After that, she will continue to carry the hatchlings on her abdomen (inset) until they can fend for themselves.

FIGURE 95: Though usually quite small, jumping spiders are easy to identify because of their uniquely forward-facing eyes and penchant for perching on flowers, like this *Habronattus amicus* on seacliff buckwheat (*Eriogonum parvifolium*).



Predatory Mites [ORDER: Acari; FAMILY: Phytoseiidae]

ADULT SIZE: <2 mm

IDENTIFICATION: Predatory mites have pear-shaped bodies and are pale to red in color, though some species take on the color of their prey after they feed. Mite larvae have six legs, while adults have eight.

DIET: The family Phytoseiidae is of particular importance to biological control of thrips and pest mites, but species in the families Anystidae (*Anystis* spp.), Laelapidae (*Hypoaspis* spp.), and Erythraeidae (*Balaustium* spp., *Augustsonella* spp.) also target various pest species.

COMMON PREY:

- Scales & mealybugs
- Whiteflies
- Aphids
- Leafhoppers
- Spider mites
- Small caterpillars (first instar)
- Fungus gnats (e.g., Sciaridae)
- Insect eggs
- Thrips
- Plant lice
- Psocids (barklice), springtails, and other small insects

SPECIES: 400+

DEVELOPMENT: Several days to several weeks (depending on weather and species)

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: Up to 10 or more

OVERWINTERING: As adults on trees or in soil debris.

PRIMARY HABITAT: Eggs are found on leaves or flowers and near groups of prey. They also eat pollen or fungal spores when prey is scarce.

CONSERVATION STRATEGIES: Cover crops, ground covers, or permanent plantings that offer alternative food and shelter should be maintained. Mites have been observed to move from cover crops into fields infested with their prey. Despite their relatively rapid rate of reproduction, it can take time to build up populations of predatory mites large enough to control pests, and populations can be quickly decimated by pesticide applications. Predatory mites are usually susceptible to the same pesticides to which spider mites and thrips have developed resistance, so generalized spraying should be avoided.

NOTE: Predatory mites can be moved into orchards by bringing mite-infested branches from trees with established predatory mite populations.

FIGURE 96: Predatory mites might be small, but they can be important biological control agents—especially in apple orchards and vineyards. *Amblyseius andersoni*[L] is an effective predator of spider and rust mites and *Typhlodromus pyri*[R] is an important predator of the European red mite (*Panonychus ulmi*).

FIGURE 97: Concrete mites (*Balaustium* spp.) have been documented to feed on a variety of orchard and crop pests, including scale insects, two-spotted spider mites (*Tetranychus urticae*), and the European red mite.

FIGURE 98: Whirligig mites (*Anystis* spp.) are generalist predators of many small pests, such as thrips, leafhoppers, and spider mites.

Harvestmen [ORDER: Opiliones; FAMILY: Phalangioidea]

FIGURE 99: While harvestmen may appear to have only one body segment, they have two (like their relatives, arachnids) that are joined so they appear as one region.

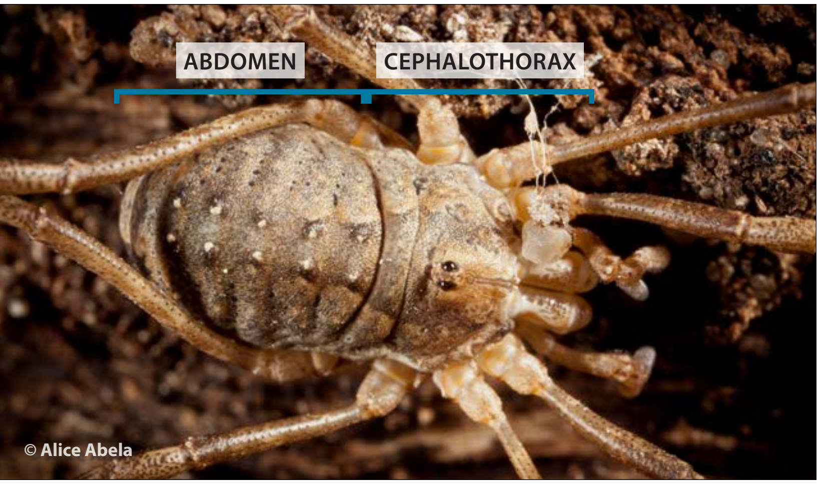
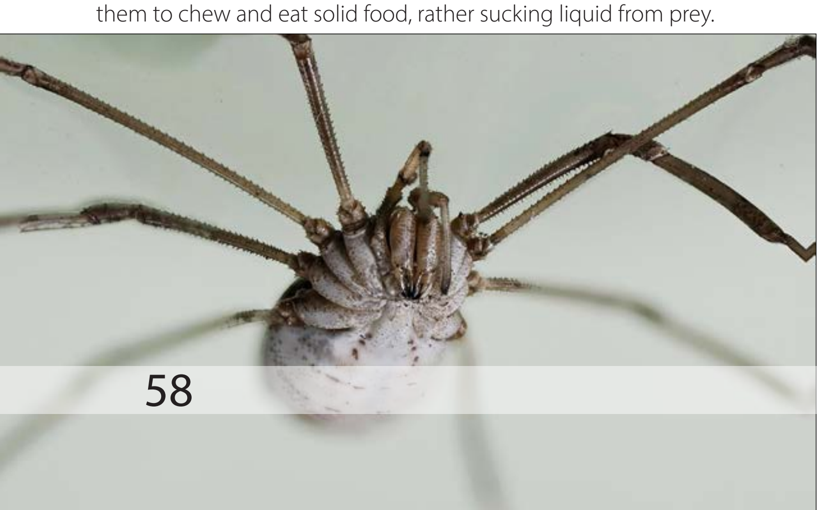


FIGURE 100: Most harvestmen are nocturnal, commonly spending the day in moist, shady areas to avoid dessication. In North America, members of the genus *Leiobunum* are widespread, and may often be found in or around vegetation or outbuildings. Opportunistic omnivores, they will eat fungi, fecal matter, and dead insects when slow-moving prey, like this caterpillar, is unavailable.

FIGURE 101: Unlike spiders, harvestmen have a four-part stomotheca (feeding apparatus) and solid jaws (chelicerae) without venom glands that allow them to chew and eat solid food, rather sucking liquid from prey.



ADULT SIZE: 3–10 mm

IDENTIFICATION: Harvestmen have two body regions that are broadly joined and appear as one. Their oval body may be 3–10 mm in length, with gray, brown, or tan color patterns. They have eight exceptionally long, stilt-like legs.

DIET: Harvestmen feed on a variety of slow-moving insects, which they chase down.

COMMON PREY:

- True bugs
- Beetles
- Moth eggs
- Caterpillars
- Earthworms
- Small insects
- Plant lice
- Snails & slugs

SPECIES: 150+

DEVELOPMENT: Up to a year

METAMORPHOSIS: Incomplete

GENERATIONS PER YEAR: 1

OVERWINTERING: Eggs overwinter in leaf litter or soil

PRIMARY HABITAT: Harvestmen can be found in gardens, field edges, grasslands, and woodlands.

CONSERVATION STRATEGIES: Limit tillage, which can harm harvestmen populations. Retain brush or straw piles as shelter. Shady, moist areas will benefit harvestmen, which require more water than other arachnids to avoid dessication. Unlike most spider species, many harvestmen species will subsist on vegetable matter and fungi when prey is unavailable—an option for them because of their unique mouthparts, which allow them to chew solid food, rather than feed on liquids.

8

Plants for Conservation Biological Control

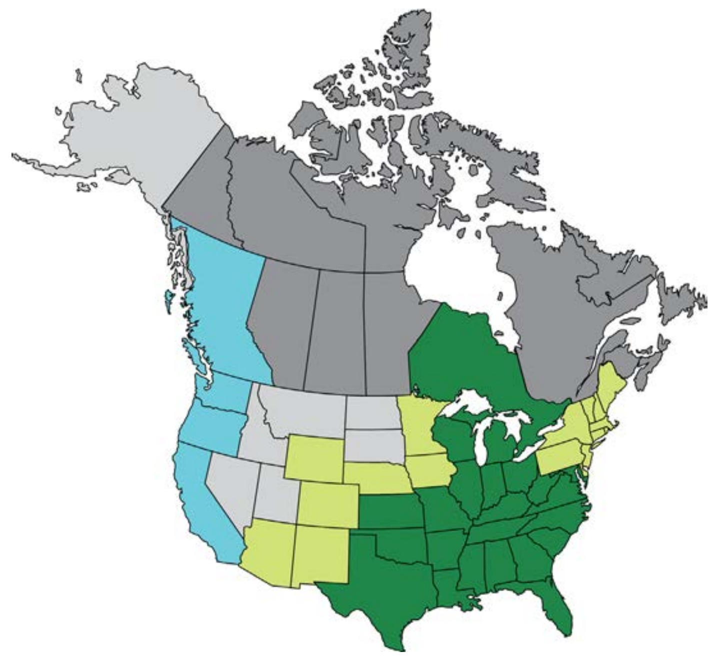
The plants listed in this section are some of the species recognized in published research, and in the authors' own observations as being particularly good for supporting the food and shelter requirements of predatory and parasitoid insects. Other species—potentially many other species—not listed here may provide equal, or even better resources for various beneficial insects, but currently, more research is needed to identify what those plant species are, and how they can be integrated into farm systems.

As discussed earlier, wherever possible, we recommend native plant species as the best option for supporting native beneficial insects. The plant species described below are mainly native trees, shrubs, wildflowers, and bunch grasses. Most of these plants prefer full sun, but vary widely in their moisture requirements. In addition to these native species, we provide a short list of low-cost, primarily non-native plants that can be used for temporary mass insectary plantings or cover crops.

For more information about the preferred site characteristics for each recommended species, see the Supports Conservation Biological Control special collection available through the Lady Bird Johnson Wildflower Center (www.wildflower.org/collections). Created in conjunction with the Xerces Society, this list can be narrowed down with additional criteria such as state, soil moisture, bloom time, and sunlight requirements.

Maps have been included with individual species to provide general information as to the historic native distribution of recommended species, based on data from the North American Plant Atlas and PLANTS Database. Range maps have not been included for widespread genera, such as hawthorn (*Crataegus* spp.), due to the number of species distributed across North America.

Figure 102: The range maps are intended to provide general information as to the native and non-native ranges of recommended species. This sample map is for lanceleaf coreopsis (*Coreopsis lanceolata*), a native wildflower historically found in the southern plains and prairies that has been introduced to western states.



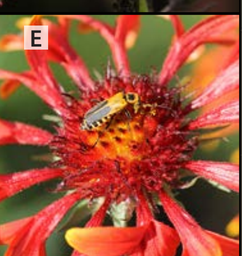
Key

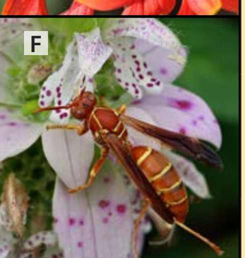
- Native species
- Native ± introduced ± naturalized species*
- Introduced species
- Potentially weedy species†
- Species absent—United States
- Species absent—Canada

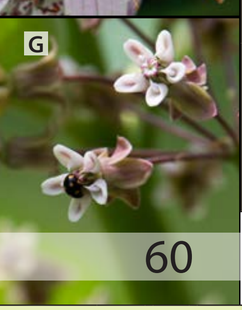
*This may include a mix of adventive natives outside their historical range, introduced non-native ecotypes or varieties, or wild populations of naturalized non-natives.

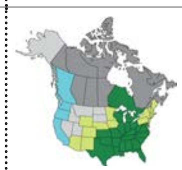
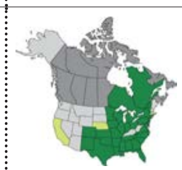
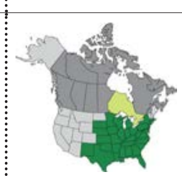
†May become weedy in certain conditions; contact your local extension office for recommendations.

Table 1: Native Wildflowers





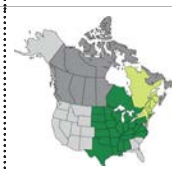
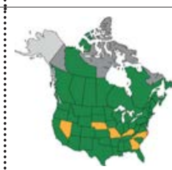
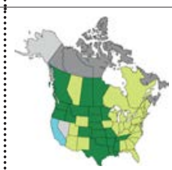
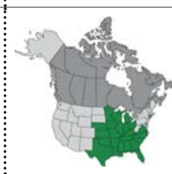


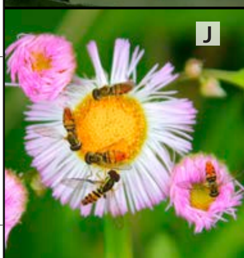
Bloom time	COMMON NAME	SCIENTIFIC NAME	Water needs	Life cycle	Height	NOTES	SPECIAL VALUE	RANGE
Early	Canadian anemone [A]	*Anemone canadensis*	M	P	1–2'	Tolerates shade	Flies Solitary wasps	
Early	Golden Alexanders [B]	*Zizia aurea*	H	P	3'	Umbel-shaped flowers; rhizomatous; adapted to disturbance; tolerates a range of soil conditions	Flies Parasitoid wasps Lady beetles Soldier beetles	
Early–Mid	Lacy phacelia	*Phacelia tanacetifolia*	L	A	3'	Prolonged bloom period with abundant pollen and nectar; can re-seed aggressively; tolerates clay soils; low-cost seed; cover crop	Syrphid flies Wasps (& bees)	
Early–Mid	Lanceleaf coreopsis [C]	*Coreopsis lanceolata*	L	P	2'	Rhizomatous, spreads without competition; thrives in poor, sandy soils; establishes quickly	Syrphid flies Solitary wasps Beetles Assassin bugs	
Early–Mid	Purplestem angelica	*Angelica atropurpurea*	H	P	3–6'	Shallow umbel-shaped flowers, can reach up to 10' tall in optimal conditions	Syrphid flies Solitary wasps	
Early–Mid	Wild buckwheat [D]	*Eriogonum* spp.	L	A; B; P	2–5'	Numerous drought-tolerant western species available; flowers prolifically; slow to establish; clump-forming	Flies Ambush bugs Solitary wasps	Widespread
Mid	Blanketflower/Indian blanket [E]	*Gaillardia* spp.	L	A; P	2'	Annual and perennial seed available in most regions; drought tolerant; adapted to disturbance; establishes easily from seed	Soldier beetles Assassin bugs Lady beetles	Widespread
Mid	Dotted mint [F]	*Monarda punctata*	L–M	P	2–4'	High-value nectar plant; establishes quickly; relatively drought tolerant; prefers sandy soil	Solitary wasps Assassin and ambush bugs	
Mid	Milkweed [G]	*Asclepias* spp.	L–H	P	1–5'	Local ecotypes among the most attractive[1]; diverse species available; toxic to livestock, but typically avoided by livestock	Highly attractive to <u>numerous</u> beneficial insects	Widespread
Mid	Mountain mint	*Pycnanthemum* spp.	M	P	3'	Shallow blossoms produce abundant nectar; highly adaptive; tolerates various soils	Solitary wasps Flies Beetles	Widespread
Mid	Partridge pea	*Chamaecrista fasciculata*	L–M	A	2'	Extrafloral nectaries at the base of leaf petioles; favors disturbed sites; establishes quickly but does not persist with competition	Small flies Wasps	

KEY Bloom time · Water needs: low (L), medium (M), high (H) · Life cycle: annual (A), biennial (B), perennial (P) · Height · May establish better from transplant than seed in some areas

Range Key

- Native species
- Native ± introduced ± naturalized species
- Introduced species
- Potentially weedy species
- Species absent—United States
- Species absent—Canada

Bloom time	COMMON NAME	SCIENTIFIC NAME	Water needs	Life cycle	Height	NOTES	SPECIAL VALUE	RANGE
Mid–Late	Boneset [H]	*Eupatorium perfoliatum*	H	P	4–5'	Prefers fertile, wet soil	Solitary wasps Ambush bugs Beetles Flies	
Mid–Late	Cup plant [I]	*Silphium perfoliatum*	M	P	8'	Forms dense colonies; pithy stems used by solitary bees and wasps for nesting sites; occasionally aggressive	Solitary wasps Parasitoids Soldier beetles Syrphid flies	
Mid–Late	Daisy fleabane [J]	*Erigeron* spp.	L–M	A; B; P	≤3'	Common and 'weedy' (planting unnecesssary); favors poor soils and disturbed sites; if not a crop weed, tolerate in field borders and out-of-the-way areas	Small syrphid flies Small parasitoid wasps	Widespread
Mid–Late	Indian hemp/ dogbane	*Apocynum cannabinum*	H	P	3–4'	Highly adaptive; can form large aggressive colonies	Flies Solitary wasps	
Mid–Late	Plains coreopsis [K]	*Coreopsis tinctoria*	L–M	A	1–2'	Drought tolerant; low cost seed; establishes quickly but does not persist with competition	Flies Solitary wasps Assassin bugs	
Mid–Late	Common yarrow [L]	*Achillea millefolium*	L	P	2'	Rhizomatous; low cost; establishes easily from seed; drought-tolerant; thrives in poor soils; tolerates competition and occasional mowing.	Flies Small wasps Ambush/ assassin bugs Beetles	
Late	Goldenrod [M]	*Solidago* spp., *Oligoneuron* spp., *Euthamia* spp.	L–H	P	2–5'	Many species of goldenrod occur throughout North America with wide adaptations to different soil types	Highly attractive to numerous beneficial insects	Widespread
Late	Rattlesnake master [N]	*Eryngium yuccifolium*	L–M	P	3–6'	Striking silver flowers; hardy plant with an extensive root system; tolerates wet or dry conditions	Flies Wasps Soldier beetles	

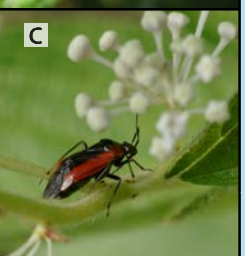


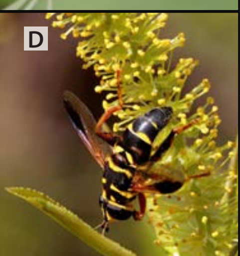
Additional Notes:

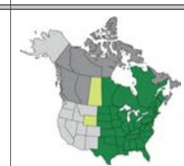
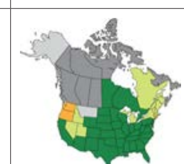
- ❶ Research conducted at Washington State University has demonstrated that locally native milkweed species are among the most attractive flowers available to various beneficial insects in the state's eastern vineyards..
- Widespread—numerous species in this genus are found across North America. Contact your local Extension office for regionally appropriate recommendations.

KEY: Bloom time; Water needs: low (L), medium (M), high (H); Life cycle: annual (A), biennial (B), perennial (P); Height; May establish better from transplant than seed in some areas

Table 2: Native Trees & Shrubs





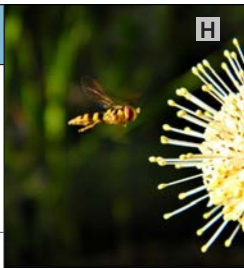
Bloom time	COMMON NAME	SCIENTIFIC NAME	Water needs	Height	NOTES	SPECIAL VALUE	RANGE
Early	Chokecherry	*Prunus virginiana*	M	20'–30'	Commonly used in hedgerows/ windbreaks; candidate for coppicing; shade tolerant; only incorporate into orchards with careful planning[1,2,3]	Wasps Syrphid flies Predatory beetles	
Early	Hawthorn	*Crataegus* spp.	L–H	20'–40'	**<u>Native</u>** species only (<u>not</u> *C. monogyna*); highly adaptable; commonly used in hedgerows; candidate for coppicing; consider before planting near orchards[1,4]	Highly attractive to <u>numerous</u> beneficial insects	Widespread
Early	Spirea (alt. meadowsweet) [A]	*Spiraea* spp.	M–H	3'–6'	Prefers wet, fertile soil; long-lasting blooms; best used in hedgerow understory or edges; pest/disease susceptible, use with caution near orchards[1]	Small flies Wasps	Widespread
Early	Wild lilac (e.g., blueblossom, New Jersey tea, etc.) [B,C]	*Ceanothus* spp. (e.g., spp. *thyrsiflorus* and *americanus*)	L–M	4'–8'	Slow to establish, but prolific once mature; many highly drought tolerant and extremely adaptable (widely used in hedgerows); tolerate clay soils; nitrogen fixing	Highly attractive to <u>numerous</u> beneficial insects	Widespread
Early	Willow [D]	*Salix* spp.	M–H	10'–60'	Early-blooming; wetland/semi-riparian species; responds well to coppicing to create thickets; may attract grape pests—avoid near vineyards; dioecious[5]	Syrphid flies Parasitoid wasps Lady beetles Diurnal fireflies	Widespread
Early–Mid	Basswood [E]	*Tilia americana*	M	60'–80' (rarely ≤100')	Best for farm reforestation efforts or as shade trees due to mature height; slow to develop, large transplants desirable for producing nectar quickly	Wasps Flies Beetles Others (bees, butterflies, etc.)	
Early–Mid	Buffaloberry	*Shepherdia* spp.	L	3'–20'	Tough prairie shrubs, excellent for slope stabilization or windbreaks in harsh/ extreme climates; tolerates highly salinity (prefers moist/ cooler soil); dioecious[5]	Various beneficial insects	Widespread
Early–Mid	False indigo	*Amorpha fruticosa*	L–M	3'–10'	Semi-riparian, may succeed in upland sites with irrigation during establishment; produces large purple flowers; may be considered weedy outside native range	Highly attractive to <u>numerous</u> beneficial insects	
Early–Mid	Elderberry [F]	*Sambucus* spp. (e.g., spp. *nigra* and *racemosa*)	M	4'–15'	Abundant, shallow flowers; pithy stems used by bees and wasps for nesting sites; tolerates coppicing; may attract grape pests—avoid near vineyards[3]; commonly used in hedgerows	Small beneficial insects Solitary wasps Predatory beetles* Syrphid flies	Widespread

KEY: Bloom time · Water needs: low (L), medium (M), high (H) · Life cycle: annual (A), biennial (B), perennial (P) · Height · May establish better from transplant than seed in some areas

Range Key

Native species	Potentially weedy species
Native ± introduced ± naturalized species	Species absent—United States
Introduced species	Species absent—Canada

Bloom time	COMMON NAME	SCIENTIFIC NAME	Water needs	Height	NOTES	SPECIAL VALUE	RANGE
Mid	Buttonbush [H]	*Cephalanthus occidentalis*	M–H	5'–20'	Excellent mid-summer blooming shrub; wetland/semi-riparian species, will tolerate periodic flooding; shade tolerant; foliage may be toxic if ingested	Highly attractive to numerous beneficial insects	
	Coffeeberry (alt. "California buckthorn")	*Frangula californica*	L	5'	Medium-sized shrub that is commonly used in CA hedgerows to attract beneficial insects; good drought tolerance; prolific flowers	Highly attractive to numerous beneficial insects	
	Toyon	*Heteromeles arbutifolia*	L	12'	CA native that has been widely cultivated outside native range; drought tolerant; survives periodic freezes; pest/disease susceptible, use with caution near orchards ❶❹	Highly attractive to numerous beneficial insects	
	Wild rose ✪ [G,I]	*Rosa* spp.	L–H	6'–8'	Semi-riparian to upland species; highly pest/disease susceptible ❸❻ (e.g.; Japanese beetles, leafrollers), but also highly attractive to wildlife	Syrphid flies Various other beneficial insects	Widespread
Late	Coyotebrush [J,K]	*Baccharis pilularis*	L	10'	Prolific late-summer blooming shrub, will sometimes flower into fall/ winter (within native range); very drought tolerant and highly adaptable; dioecious ❺	Highly attractive to numerous beneficial insects	
	Oceanspray	*Holodiscus discolor*	M–H	6'–20'	Important late-season nectar resource; highly adaptive; tolerates a wide variety of soil conditions (wet, dry, rocky); tolerates sun or shade ❶	Highly attractive to numerous beneficial insects	



Additional Notes:

❶ Alternate host for fire blight.

❷ Potential host for BMSB (see *Host Plants of the Brown Marmorated Stink Bug in the U.S.* for details. A publication of the Brown Marmorated Stink Bug IPM Working Group in conjunction with the Northeastern IPM Center: www.stopbmsb.org/where-is-bmsb/host-plants/)

❸ Potentially useful as a "banker plant," a noncrop plant that can provide ongoing pest populations to sustain beneficial parasitoids and predators[G]

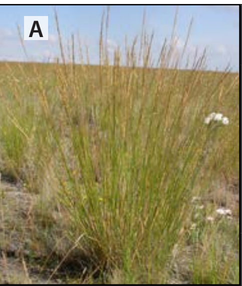
❹ Alternate host for apple maggot

❺ Dioecious (i.e., pollen-producing (male) and nectar-producing (female) flowers found on separate plants). Only female plants produce fruit.

❻ Potential host for spotted wing drosophila

✪ Widespread (numerous species in this genus are found across North America). Contact your local Extension office for regionally appropriate recommendations.

Table 3: Native Bunch Grasses



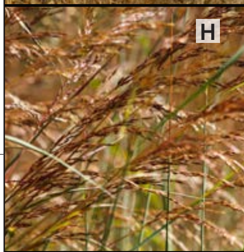
Bloom time	COMMON NAME	SCIENTIFIC NAME	Water needs	Life cycle	Height	NOTES	SPECIAL VALUE	RANGE
Cool	Blue wild rye	*Elymus glaucus*	L	P	3.5'	Thick root system, good for stream bank stabilization; favors disturbed sites; fire tolerant; tolerates a wide variety of soil conditions	Beetles Spiders Various other beneficial insects	
	Bluebunch wheatgrass [A]	*Pseudoroegneria spicata*	L	P	4'	Extremely drought tolerant; tolerates a wide variety of soil conditions, prefers well-drained soils; good for erosion control and bank stabilization	Beetles Spiders Various other beneficial insects	
	California oatgrass ✱	*Danthonia californica*	M	P	2'	Wetland to semi-riparian species; tolerates a wide variety of soil conditions, prefers moist, fertile soil; favors disturbed sites; high seed dormancy rate	Beetles Spiders Various other beneficial insects	
	Canada wild rye [B]	*Elymus canadensis*	M	P	4'	Rhizomatous; establishes easily from seed; excellent for erosion control and stabilization; shade tolerant; drought tolerant; prefers coarse or rocky soils	Beetles Spiders Various other beneficial insects	
	Idaho fescue [C] & Roemer's fescue	*Festuca idahoensis* *F. i. ssp. roemeri*	L	P	2'	Roemer's fescue limited to CA, OR, WA, and BC; extensive, deep root system; drought resistant; high value forage; tolerates disturbance and poor soils; cold tolerant	Beetles Spiders Various other beneficial insects	
	Prairie Junegrass [D]	*Koeleria macrantha*	M	P	2'	Slow growing, but may spread into neighboring areas in ideal conditions; cold, heat, and drought tolerant; prefers well-drained soils	Beetles Spiders Various other beneficial insects	
	Slender wheatgrass	*Elymus trachycaulus*	M	P	3'	Establishes quickly from seed; favors disturbed sites; short-lived; tolerates a wide variety of soil conditions, especially in high saline and reclaimed areas	Beetles Spiders Various other beneficial insects	
	Wiregrass	*Aristida beyrichiana*	M	P	4'	High drought tolerance; favors disturbed sites; fire adapted; can become aggressive without competition or at high seeding rates	Beetles Spiders Various other beneficial insects	

KEY: Bloom time; Water needs: low (L), medium (M), high (H); Life cycle: annual (A), biennial (B), perennial (P); Height; ✱ May establish better from transplant than seed in some areas

Range Key

Native species	Potentially weedy species
Native ± introduced ± naturalized species	Species absent—United States
Introduced species	Species absent—Canada

(Bloom time)	COMMON NAME	SCIENTIFIC NAME	(Water needs)	(Life cycle)	(Height)	NOTES	SPECIAL VALUE	RANGE
Warm	Big bluestem [E]	*Andropogon gerardii*	M	P	3'–10'	Rhizomatous; tolerates a wide variety of soil conditions; can be aggressive at high seeding rates	Syrphid flies Beetles Spiders Various other beneficial insects	
Warm	Deergrass [G]	*Muhlenbergia rigens*	M	P	5'	Prefers sandy or well-drained soils; excellent for streambank stabilization; used for overwintering by lady beetles in CA; shade tolerant	Beetles Spiders Various other beneficial insects	
Warm	Eastern gamagrass	*Tripsacum dactyloides*	H	P	3'–9'	Rhizomatous; wetland to semi-riparian species; prefers fertile soils, but highly adaptable; excellent for filter strips; extremely palatable to livestock/ wildlife	Beetles Spiders Various other beneficial insects	
Warm	Indian grass [H]	*Sorghastrum nutans*	M	P	3'–8'	Excellent for erosion control and mixing with other native prairie plants; fire-adapted; can be aggressive at high seeding rates	Beetles Spiders Various other beneficial insects	
Warm	Little bluestem [I]	*Schizachyrium scoparium*	L	P	1'–3'	Highly variable depending on site conditions; tolerates sandy and clay soils; deer resistant; considered weedy in cranberry bogs	Beetles Spiders Various other beneficial insects	
Warm	Prairie dropseed (may establish better from transplant) [J]	*Sporobolus heterolepis*	L	P	3'	Long-lived, but slow to establish from seed; does not readily spread from seed; tolerates a wide variety of soil conditions, prefers well-drained soils; drought tolerant	Beetles Spiders Various other beneficial insects	
Warm	Sideoats grama [F,K]	*Bouteloua curtipendula*	L–M	P	2'–4'	Rhizomatous; drought and cold tolerant; prefers medium-textured, well-drained soils; good for erosion control and bank stabilization; highly adaptive	Beetles Spiders Various other beneficial insects	



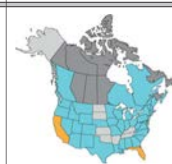
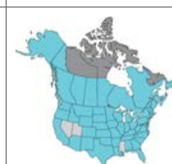
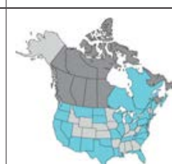
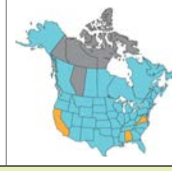
Additional Notes:

Widespread—numerous species in this genus are found across North America. Contact your local Extension office for regionally appropriate recommendations.

KEY: Bloom time | Water needs: low (L), medium (M), high (H) | Life cycle: annual (A), biennial (B), perennial (P) | Height | May establish better from transplant than seed in some areas

RECOMMENDED PLANTS

Table 4: Cover Crops

Bloom time	COMMON NAME	SCIENTIFIC NAME	Water needs	Life cycle	Height	NOTES	SPECIAL VALUE	RANGE
Early-Mid	Lacy phacelia	*Phacelia tanacetifolia*	L	A	2'	California native wildflower; used extensively in Europe and North America as an annual cover crop for weed suppression and capturing excess nitrogen; abundant nectar and pollen	Flies Wasps Beetles	
Early-Mid	Sweetclover (yellow [A], white [B])	*Melilotus officinalis, M. albus* var. *annua*	H	B	3–6'	Most sweetclover varieties are biennial, cv. 'Hubam' is an annual, producing flowers in a single season; establishes quickly from seed; prefers warm, dry climates	Flies Wasps Beetles	
Early–Late	Clover [C]	*Trifolium* spp.	L	A; P	2–5'	Perennials: red (*T. pratense*), white (*T. repens*)[B], and alsike (*T. hybridum*). Annuals include crimson (*T. incarnatum*) and berseem (*T. alexandrinum*)	Wasps Soldier beetles	Widespread
Early–Late	Hairy vetch [D]	*Vicia villosa*	L	A; B; P	2'	Most cold tolerant *Vicia* are usually fall sown, even in northern climates to provide cool season cover; often interseeded with rye for support	Highly attractive to numerous beneficial insects	
Mid–Late	Alyssum [E]	*Lobularia maritima*	M	A	1'	Low cost, low growing, easy to maintain; can be mass-planted between rows of vegetables; may attract brassica-feeding pests (e.g., flea beetles, harlequin bugs)	Highly attractive to numerous beneficial insects	
Mid–Late	Bachelors button [F]	*Centaurea cyanus*	M	A	3'	Very low cost seed; suitable for mass plantings to create temporary habitat; will readily self-sow under optimal conditions	Solitary wasps Flies Beetles	
Mid–Late	Buckwheat [G]	*Fagopyrum esculentum*	M	A	2'	Traditional pseudo-cereal summer cover crop; develops quickly in warm weather; flowers prolifically, attracting large numbers of beneficial insects	Small flies Wasps	
Mid–Late	Cilantro [H]	*Coriandrum sativum*	M	A	2'	Low cost, readily available seed; small, shallow flowers of cilantro are highly attractive to many small parasitoid wasps and other beneficial insects	Wasps Soldier beetles Flies	
Mid–Late	Dill [I]	*Anethum graveolens*	M	A	3'	Low cost, readily available seed; small, shallow flowers of dill are highly attractive to many small parasitoid wasps and other beneficial insects	Flies Wasps	
Mid–Late	Mustard (e.g., Indian mustard [J], white mustard [K])	*Brassica* spp. (e.g., *B. juncea*, *Sinapis alba*)	M	A	1–4'	May help suppress weeds and nematodes; NOTE: consider before planting, some spp. also support commercial brassica pests/diseases	Flies Wasps Beetles	Widespread
Mid–Late	Oilseed radish	*Raphanus sativus*	M	B	3'	Plant in spring to encourage flowering; sometimes used to loosen soil and suppress nematodes; may support commercial brassica pests/diseases	Flies	

KEY: Bloom time; Water needs: low (L), medium (M), high (H); Life cycle: annual (A), biennial (B), perennial (P); Height; May establish better from transplant than seed in some areas

Range Key

- Native species
- Native ± introduced ± naturalized species
- Introduced species
- Potentially weedy species
- Species absent—United States
- Species absent—Canada

Additional Notes:

Widespread—numerous species in this genus are found across North America. Contact your local Extension office for regionally appropriate recommendations.

Hoverfly larvae feeding on aphids.

Additional Resources

Publications & Fact Sheets

Identification Guides

A Pocket Guide to the Common Natural Enemies of Crop and Garden Pests in the Pacific Northwest
Oregon State University Extension
www.ipmnet.org/Posters_and_Presentations/Pocket_Guide_Natural_Enemies.pdf

Beneficial Insects and Spiders in Your Maine Backyard
University of Maine Cooperative Extension *Bulletin #7150*
http://umaine.edu/publications/7150e/

Beneficial Insects, Spiders, and Other Mini-Creatures in Your Garden
Washington State University Cooperative Extension
http://cru.cahe.wsu.edu/CEPublications/EM067E/EM067E.pdf

Flower Flies (Syrphidae) and Other Biological Control Agents for Aphids in Vegetable Crops.
University of California
http://anrcatalog.ucdavis.edu/pdf/8285.pdf

Habitat Installation & Assessment

Attracting Beneficial Insects with Native Flowering Plants
Michigan State University Extension
http://nativeplants.msu.edu/uploads/files/E2973.pdf

Conservation Buffers: 5.2 Plants that Attract Beneficial Insects
USDA National Agroforestry Center
http://nac.unl.edu/buffers/guidelines/5_protection/2.html

Cover Cropping for Pollinators and Beneficial Insects
Sustainable Agriculture Research and Education
www.sare.org/Learning-Center/Bulletins/Cover-Cropping-for-Pollinators-and-Beneficial-Insects

Farming for Wildlife: Beetle banks
The Royal Society for the Protection of Birds
https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/advice/details.aspx?id=204246

Farmscaping for Beneficials: A Community-Based Biological Control Program
Oregon State University
www.ipmnet.org/Posters_and_Presentations/Farm-scaping_a_community-based_biocontrol_program.pdf

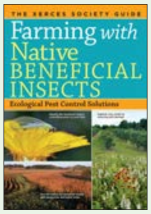
Plants Enhancement Activity (PLT08) Habitat Development for Beneficial Insects for Pest Management
USDA Natural Resources Conservation Service
www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_007850.pdf

Plants That Attract Beneficial Insects
University of Florida Extension
http://brevard.ifas.ufl.edu/horticulture/PDF/attracting_beneficials.pdf

PNW Insect Management Handbook: Integrated Pest Management
Table 2. Flowering plants visited by beneficial insects that can aid biological control conservation efforts
Oregon State University
http://insect.pnwhandbooks.org/sites/insect.pnwhandbooks.org/files/pdfsection/ipm.pdf#page=6

Practical Guidelines for Establishing, Maintaining, and Assessing the Usefulness of Insectary Plantings in Your Farm
Oregon State University
www.ipmnet.org/Posters_and_Presentations/Farm_Insectary_Plant_Manual_Draft2_Pressqual1.pdf

More from the Xerces Society



Farming with Native Beneficial Insects
Harness natural pest control with The Xerces Society's latest book, *Farming with Native Beneficial Insects*. Authors Eric Lee-Mäder, Jennifer Hopwood, Mace Vaughan, Scott Hoffman Black, and Lora Morandin discuss the ecology of native beneficial insects and how to increase their numbers on your farm through simple conservation strategies.

Lady beetles, syrphid flies, lacewings, and other beneficial insects prey upon crop pests, reducing or eliminating the need for pesticides. This comprehensive guide describes how to recognize these insects and their habitat, and how to evaluate, design, and improve habitat for them. Close-up photography and in-depth profiles familiarize you with more than 20 beneficial insects and their kin. Step-by-step illustrated instructions detail specific solutions including native plant field borders, mass insectary plantings, hedgerows, cover crops, buffer strips, beetle banks, and brush piles.

> *"If you are a grower or a backyard gardener, this is a 'must have.' Readable and filled with gorgeous photos and handy charts, this book provides reams of information about how to get the upper hand on your pest issues with reduced or no pesticide use."*
> —Claire Kremen, professor and co-director of the Berkeley Food Institute, University of California–Berkeley

Available in bookstores and on the Xerces Society's website www.xerces.org/farming-with-native-beneficial-insects/

Beneficial Insect Habitat Assessment Guide: Farms and Agricultural Landscapes
This habitat assessment guide was designed to help educate conservation planners and landowners, prioritize conservation actions, and quantify habitat or land management improvements for beneficial insects on a single site.
www.xerces.org/habitat-assessment-guides/

Beyond the Birds and the Bees: Effects of Neonicotinoid Insecticides on Agriculturally Important Beneficial Insects
This report details potential negative impacts of neonicotinoid insecticides on important beneficial insects. It also makes recommendations on how we can better protect important beneficials like beetles and wasps.
www.xerces.org/beyond-the-birds-and-the-bees/

Pesticide Risk Reduction

Adamson, N., T. Ward, and M. Vaughan. 2012. Designed with pollinators in mind. *Inside Agroforestry* 20(1):8–10. http://nac.unl.edu/documents/insideagroforestry/vol20issue1.pdf

Bentrup, G. 2008. *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways*. 110 pp. Asheville, NC: USDA Forest Service, Southern Research Station. http://nac.unl.edu/buffers/docs/conservation_buffers.pdf

Books

Altieri, M., Nicholls, C., and M. Fritz. 2005. *Manage Insects on Your Farm: A Guide to Ecological Strategies*. SAN Handbook Series Book 7. 119 pp. Beltsville, MD: Sustainable Agriculture Network. http://www.sare.org/Learning-Center/Books/Manage-Insects-on-Your-Farm

Barbosa, P. (ed.). 1998. *Conservation Biological Control*. 396 pp. New York: Academic Press.

Bellows, T. S., Jr., and T. W. Fisher (eds.). 1999. *Handbook of Biological Control: Principles and Applications*. 1046 pp. San Diego: Academic Press.

Flint, M. L., and S. H. Dreistadt. 1998. *Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control*. 154 pp. Berkley: University of California Press.

Gurr, G. M., S. D. Wratten, and M. A. Altieri (eds.). 2004. *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*. 238 pp. Collingwood, VIC, Australia: CSIRO Publishing. http://biocontrol.ucr.edu/irvin/ecological_engineering_gurr_et_al.pdf

Phatak, S. C. 2001. *Managing Pests with Cover Crops. In Managing Cover Crops Profitably*. SARE Handbook Series Book 9, 3rd Ed., 25–33. Beltsville, MD: Sustainable Agriculture Network. http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition

Pickett, C., and R. L. Bugg (eds.). 1998. *Enhancing Biological Control: Habitat Management to Promote Natural Enemies of Agricultural Pests*. Berkeley: University of California Press.

Websites

ATTRA: Farmscaping to Enhance Biological Control
https://attra.ncat.org/attra-pub/summaries/summary.php?pub=145

Conservation Biological Control Resources
Links to fact sheets, websites, and other Xerces Society resources.
www.xerces.org/conservationbiocontrol/

Michigan State University: Enhancing Beneficial Insects with Native Plants
Native Plants and Ecosystem Services
http://nativeplants.msu.edu/

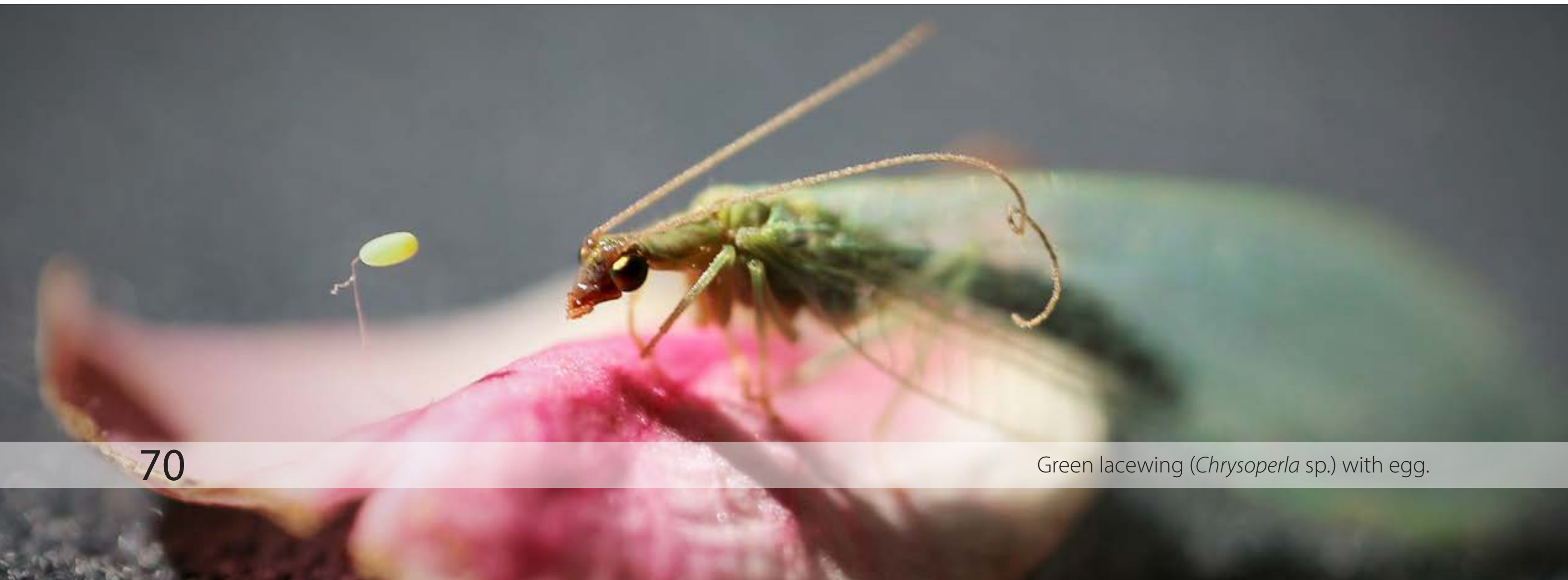
Sustainable Agriculture Network: A Whole-Farm Approach to Managing Pests
This 20-page bulletin helps farmers and educators design farm-wide approaches to pest control.
www.sare.org/Learning-Center/Bulletins/A-Whole-Farm-Approach-to-Managing-Pests

University of California: Habitat Manipulation to Enhance the Effectiveness of Aphidophagous Hover Flies (Diptera: Syrphidae)
http://asi.ucdavis.edu/programs/sarep/past/sarep-newsletters-1/newsletters-winter1992-vol5no2.pdf

University of Connecticut: Use of Cover Crops and Green Manures to Attract Beneficial Insects
www.ipm.uconn.edu/documents/view.php?id=6

University of Florida: Featured Creatures
In-depth profiles of beneficial insects, crop pests, and other organisms, including numerous search functions.
http://entnemdept.ufl.edu/creatures/

University of Wisconsin: Beneficial Insect Habitat in an Apple Orchard—Effects on Pests
www.cias.wisc.edu/crops-and-livestock/beneficial-insect-habitat-in-an-apple-orchard%C2%97effects-on-pests/



Green lacewing (*Chrysoperla* sp.) with egg.

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Additional Acknowledgments

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The Xerces Society/Jessa Kay Cruz: Figures 12, 19, 22, 31, 32, 33

The Xerces Society/Sarah Foltz Jordan: Figures 8, 13, 15, 20, 29, 30, 37[TL], 38, 58, 65, 66[BR,BL], 68[N], 70, 82, 88[TR], 89[TR], 90[L], 91; Tables 1[M], 3[D]

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The Xerces Society/Sara Morris: "Assassin bug/Ambush bug," "Predatory stink bug," "Lacewings," "Rove beetle," "Flower fly," "Thread-waisted wasp," "Tachinid fly," "Chalcidoidea wasp," Scarab-hunting parasitoid wasp," *Actual Size* silhouettes (p. 37–62); *Plants for Conservation Biological Control* range maps (p. 65–73) using data provided by the The Biota of North America Program's North American Plant Atlas (www.bonap.org), the USDA–NRCS's PLANTS Database (http://plants.usda.gov), and the Beneficial Insect Collection Database, available through the Lady Bird Johnson Wildflower Center (www.wildflower.org/collections).

Beneficial insects are integral to healthy agricultural ecosystems and to our environment. Around the world, these wild insects prey upon and parasitize crop pests, recycle excess nutrients, aerate and improve soil quality, and support other wildlife in vast food chains.

This publication outlines the ecology of many native beneficial insect groups and highlights recommended strategies for conservation biological control—the practice of providing habitat for insects that attack crop pests. While native predator and parasitoid insects alone may not solve all of a producer's pest problems, they can be an important part of an Integrated Pest Management system and contribute to reduced need for pesticides over time.

2016-020