WINGS

ESSAYS ON INVERTEBRATE CONSERVATION

THE XERCES SOCIETY FALL 2022

CONTENTS

Understanding the natural history of the species we work with is the foundation of our efforts to protect invertebrates and their habitats. We at Xerces are completely enthralled by the amazing behaviors, intriguing relationships, and eye-catching beauty of these animals. This issue of *Wings* features bees, butterflies and wasps, and dragonflies. We hope you find them as entrancing as we do.

Turning over Rocks Can Lead to Life-Defining Discoveries

Scott Black

When I was a kid, natural history (although I'd not have called it that at the time) is how I got excited about insects and other invertebrates that lived in my neighborhood. Although I thought each individual insect was cool, what they did was even cooler. Seeing a butterfly laying an egg on a particular plant, moving a log and glimpsing the frantic activity in a partially exposed ant nest, or lifting a rock from a stream and inspecting a caddisfly with a case it had made of small pebbles—these kinds of encounters are what spurred my interest in finding out more about what these animals were and how they lived.

Understanding natural history is vital to our conservation efforts at Xerces. How can you protect or restore habitat for a species unless you know where and how it spends its life? Take a butterfly, for instance. Does it have one generation a year, or two, or more? How long does it take for the butterfly to go through its cycle from egg to caterpillar to chrysalis? Does the species overwinter (or oversummer during droughts) as an egg, caterpillar, or chrysalis? What host plant (or plants) does its caterpillars eat, and therefore on which does the butterfly lays its eggs? Where does that host plant grow—wet areas? disturbed areas along roadsides?—and when does it grow? Are there any special require-

Silver-banded hairstreak laying eggs. In the United States, this butterfly is found from California to Texas as well as in Florida. Photograph by Bryan E. Reynolds.

ments that help this species, such as ants that tend its larvae? Answering these questions is vital to determining what needs to be done to protect, conserve, and manage habitat for these insects.

Unfortunately, we conservationists often lack vital information about insects and other invertebrates. Take the case of the mardon skipper (*Polites mardon*). When I started working on this butterfly almost twenty years ago, we knew that it was likely declining across its range, but we did not know much about its habitat needs, threats to its habitat, or the extent of its decline. And, as we were to discover, some of what we thought we knew about this insect turned out to be, at best, an incomplete picture.

The common wisdom was that mardon caterpillars fed almost exclusively on a grass called fescue, but once we started looking we began to understand that, although fescue was preferred at most locations, female mardon skippers lay eggs on multiple species. Studies that I undertook with Loni Beyer showed that in southern Oregon they prefer California oatgrass (*Danthonia californica*). Loni then joined Cheryl Shultz's lab at Washington State University Vancouver and further research that they conducted with Erica Henry showed that, in the Cascade Range in Washington, females prefer to oviposit on sedges (*Carex* spp.) at one location and oatgrass (*Danthonia* spp.) at another; and in the lowland prairies of the Puget Sound, they prefer Roemer's fescue (*Festuca idahoensis*). Further, although it was widely believed that mardon skippers overwinter as chrysalises, preliminary studies suggest that Cascade populations overwinter as caterpillars.

Work by Xerces and our colleagues also showed that conifer encroachment onto meadow habitats is a major threat. Because of their limited dispersal ability and an increase in distance between suitable habitat, mardon skippers are not able to move across the landscape, potentially leading to local extinctions. Complicating this is that prescribed fire, which is often used to deal with conifer encroachment, can eliminate resident mardon populations.

I led a study in California that found substantially fewer mardon skippers in burned areas of meadows compared to unburned areas. One solution is to hand cut conifers and remove them from the most densely occupied mardon areas. Another is to ensure that we do not burn an entire meadow where the butterflies live, allowing them to recolonize from the unburned portion.

Our work on this butterfly has been a success. Applying this knowledge and working with partners at the U. S. Forest Service and the Bureau of Land Management, we have protected many sites across the range of this butterfly, helping to ensure that it remains with us for future generations.

At Xerces, understanding the life history of the animals we are working to protect is vital to our success. That is why we have partnerships with researchers and community scientists to help understand natural history, conduct surveys to determine where these animals live, and focus on understanding threats and the management actions that will alleviate those threats.

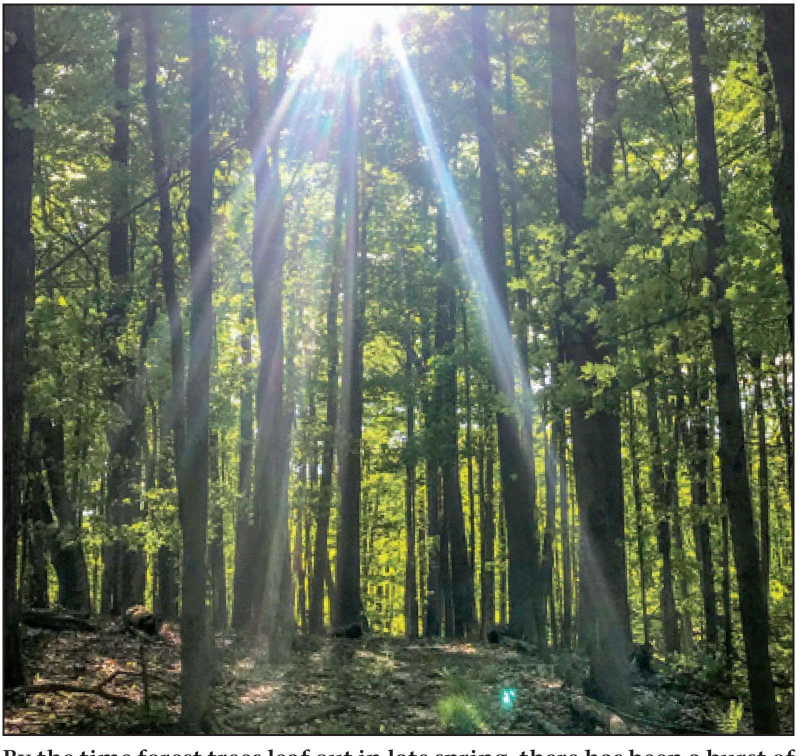
Who'd have thought that the intriguing behavior of the animals I spent time watching as a kid would still be a core part of what I focus on every day?

The Secret Life of Forest Bees

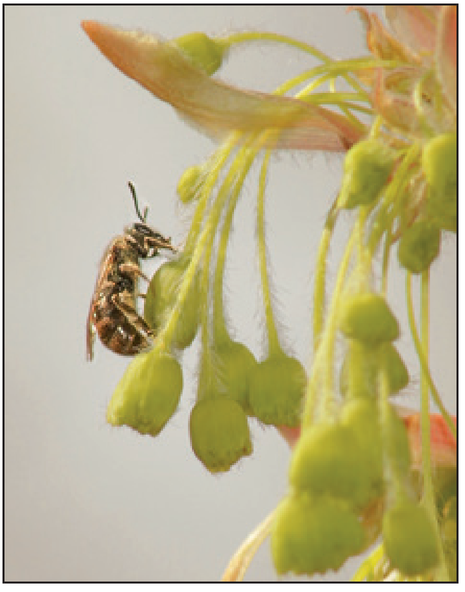
Kass Urban-Mead

It's a cool April day in the woods around Trumansburg, a small town on the shores of Lake Cayuga in the Finger Lakes region of New York state. Despite our heavy packs, my friend Greg and I step gingerly to avoid crushing bloodroot, early meadow-rue, and trout lily. An hour later, at the base of a large sugar maple tree, we've unpacked and begun our safety run-down using an alphabet-based mnemonic. **A**nchor? Check; safely in place. **B**elts and buckles? Check; all tight. **C**arabiner? Check; and three extra for good measure. **D**evices? Check; my extra-long-handled butterfly net and several jars tied onto the climbing belt. **E**nd of rope? Check; securely tied and tangle free. And finally: **F**riends? Of course, one never climbs alone.

A slight breeze rustles the branches overhead, and I take the first big step of my long vertical climb.



By the time forest trees leaf out in late spring, there has been a burst of activity from bees foraging on the flowers blooming on the forest floor and in the canopy. Photograph by Kass Urban-Mead.



Trees have been called "meadows in the sky" because of their huge number of flowers. The author had the rare chance to study bees in the canopy. Photograph by Patrick Coin.

Slowly and steadily, I ascend to the strong crotch near the top of the tree, where the rope, which was flung up there using a giant slingshot before I began climbing, loops back to the ground. This is as high as I can go. I'm at about sixty-five feet, with a side view of the branches of oak, tulip tree, and the occasional sugar maple reaching to the sky. Some have begun to push out their sweet, pea-green, early spring leaves, while others are still bare twigs displaying only buds or early flowers. Midstory red maple, hop hornbeam, and black cherry grab the sunshine between them in the airspace below. My body gets accustomed to the regular swaying of the branches, and I wave to Greg, who is now tiny, distant on the dappled forest floor.

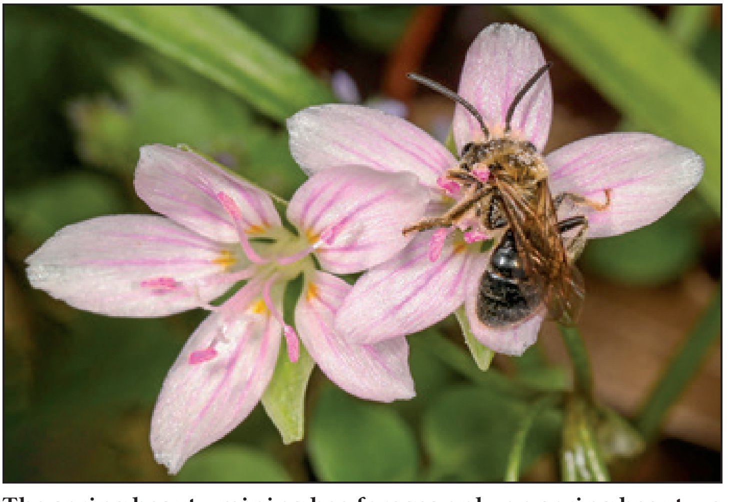
I grab my net as a gust of wind dies down, and focus on the dangling sugar maple catkins, waiting for the magic to begin. A bumble bee queen buzzes in, and three bee-mimicking flower flies land on a mature catkin bursting with pollen. I notice a metallic green sweat bee, and then several mining bees, both male and female. A cellophane bee, more commonly found on the earlier-blooming red maple, even deigns to drop by. The average sugar maple tree makes a hundred billion pollen grains; the oaks that bloom a few weeks later make even more; and—to my absolute delight—it seems that the bees have figured it out.

These climbs and observations were part of my dissertation work at Cornell University, where I collaborated with an amazing team of scientists to try to answer a simple question: Why do apple orchards with forests nearby have more bees in them? Indeed, there is consistent evidence that agricultural fields that are near forests, hedgerows, and woodlots have both more bees and more kinds of bees. Moreover, Mia Park, then also at Cornell, showed that having more nearby natural habitat somewhat mitigated the negative effects of high pesticide loads on bees visiting apple orchards.

Before Europeans arrived, the area that is now the northeastern United States was mostly covered in forest, so some sort of relationship between bees and woods makes sense. Forests have always included regular disturbances—gaps and patches of varying sizes were created by beaver dams, windstorms, and fire, often through intentional indigenous management—which created a varied matrix of heterogeneous habitat. This was true before colonial land clearing, and it is true now that our second-growth forests have regrown, bearing with them the legacies of pastures and crop fields. So, although we correctly think of bees as creatures that vibrantly fill our gardens, meadows, and fields, the six hundred species that occur in the region evolved in a forested landscape. Some bees are harder to see, but there are many that you can discover with no climbing required.

At ankle height are the bees who visit spring ephemerals—flowers that bloom in sunshine during the period between winter and when the canopy trees fully leaf out, plunging the forest floor into the deep shadow of summer. One well-known forest-floor forager is the spring beauty mining bee (*Andrena erigeniae*). As with other solitary species, each female builds her own nest, a series of small chambers off of an underground tunnel, each chamber supplied with a pile of pollen large enough to feed a single baby bee. She is a specialist, collecting pollen only from the flowers of two species of spring beauty (*Claytonia*). Her leg hairs are adapted to be just the right size and shape for gathering spring beauty pollen, and are so efficient that she barely drops any of it as she forages. There are other mining bee species that specialize on plants such as bellwort, geranium, and trout lily. This specialization is possible because the bees are active as adults for only the brief window during which their host flowers bloom, and otherwise wait out the year turning slowly from eggs to larvae to pupae, deep underground in their nests.

Shift your gaze from the flowers toward the leaf litter, and you're perfectly poised to find bees scouting for nest sites. Bumble bee queens, having mated in the fall and hibernated all winter, diligently pursue their need to establish nests. I usually see bumble bees searching for nest sites in the woods, on well-drained, sloping hillsides that are cov-



The spring beauty mining bee forages only on spring beauty, a wildflower that blooms on the forest floor early in the year. By the time the tree canopy leafs out, the flowers and the bees disappear, and the cycle repeats the next year. Photograph by Judy Gallagher.

ered with leaf litter. Because bumble bees are active all season, they cannot afford to specialize on just a single type of flower—they'd be hungry when it stops blooming!—so you'll instead see them visit a wide range of flowers for the energy to support their colonies. They are hairier and messier than the specialists, and as a result are particularly good pollinators, dropping pollen onto flowers as they look for food.

Another bee you're likely to see weaving across the forest floor in early spring is a master of disguise. Bees in the genus *Nomada* are cuckoo bees, meaning they don't build nests of their own. Instead, a cuckoo bee camouflages itself with a special chemical perfume, sneaks inside another bee's nest, and lays an egg on the pollen the host bee has gathered. Cuckoos have a wasp-like look, with red or yellow markings and thickened exoskeletons to protect them in case they get caught. When the cuckoo larva hatches, it kills the mining bee larva and eats all of the pollen. It's easy to imagine someone casting cuckoos as villains, but researchers believe that seeing them year after year is actually a good sign, since abundant cuckoo bees suggest an abundant population of host bees.

The next strategy for forest-bee spotting: if it's green and glinting, check it out! Many forest insects are gorgeously iridescent, probably because their sheen confuses predators when they fly between dappled sun and shade. Two of my favorite forest bees shimmer in the dappled light: the metallic green *Augochlora pura* and the shiny blue *Lasioglossum coeruleum*. They're active all summer, have generalist diets, and will usually build their burrows in abandoned beetle holes of an eighth to five-sixteenths of an inch (three to eight millimeters) in diameter in dead wood. Stumps, standing snags, and debris are crucial habitat for these bee species. Other stem- and cavity-nesting bees, such as mason bees, also using pre-

Cuckoo bees in the genus *Nomada*, commonly called nomad bees, do not make their own nests. They lay eggs in the nests of other bees, frequently those of mining bees. Photograph by Bryan E. Reynolds.

The metallic-hued *Augochlora* bees nest in tunnels in rotting wood such as standing snags and fallen logs. They may have two or three generations each year. Photograph by Katja Schulz.

existing beetle holes or hollow pithy stems of plants.

You may be surprised that sugar maple and oak trees host bees. Indeed, trees in the northeastern forest have not usually been considered bee forage because many, such as poplar, ash, birch, alder, hickory, and oak, are wind-pollinated. This makes sense: it is windy, cold, and often rainy in spring, so most spring-blooming trees take advantage of that air movement and spread their pollen in the breeze, rather than relying on small insects that don't like the cold to make the journey up to their flowers. But, since the trees make billions of protein-filled grains, many bees gather and bring the pollen home to rear their young anyway.

Although not widely studied, one recent review paper pulled together every incidental mention in old literature records of pollen collection from wind-pollinated plants. They found two hundred pollen-collection records from more than a hundred genera of wind-pollinated plants. For example, old natural-history papers note that mason and mining bees love oak, while metallic green sweat bees visit walnut trees. In New York apple orchards, Laura Russo, while a postdoc at Cornell, had identified lots of pollen carried by bees and found that they also carried some maple, willow, ash, and birch pollen.

Inspired by this prior research, I started my dissertation field work in March 2017 and continued it during the next two springs. Using special bee traps in eleven forests and woodlots adjacent to orchards, I found more than ninety species of wild bees active in the forest canopy between March and the end of May. After then spending long pandemic months staring at bees under a microscope, I found that tree pollens often make up between 25 and 100 percent of the pollen in an individual bee's digestive tract. Oak and maple were the primary trees visited for pollen, but I also occasionally found beech, walnut, ash, and birch. In my study area, the canopy trees were a big part of bees' diets before apple orchards bloomed; once the fruit trees bloomed, the bees were more abundant in the orchards, and their diets

Orchards that are adjacent to forests have more diversity and abundance of bees. In the early spring the forests support bee populations, which then move into the orchards when the fruit trees bloom. Photograph by the Xerces Society / Kelly Gill.

transitioned to include both canopy pollens and lots of apple pollen. It was obvious that many bees moved from the forests to the orchards during apple bloom.

Although research on forest bees is increasing, we have really just scratched the surface when it comes to understanding them. These bees forage for pollen in forests, but also use canopy trees as places in which to collect honeydew and resins, glean resources for self-medication, hide out in microclimates buffered against temperature extremes, and gather on tall trees sought out as mating sites. We have much more to learn there about each of these!

One thing we do know is that for these bees to persist, they need the right forest conditions. Most forest ownership in the Northeast is private, so actions taken on back woodlots and private properties can have huge implications for conservation. These bees might rely on the presence of the tree canopy, but it is vital that we not stop managing woodlands or cease cutting trees: the openings in these forests are also very important for supplying the resources that help provide for the entire life cycle of bees. Ecological forestry also helps maintain tree diversity, creates a variety of niches for wildlife, and keeps forests resistant to pathogens and resilient in the face of climate change. According to research from Rutgers University, about a third of bee species in the Northeast seem to rely heavily on forest habitats, while other species need both forests and fields, and move frequently between them. Still other bees can thrive in more-developed landscapes. So, in order to support all of the species, we need a landscape with forests, openings, meadows, and every habitat in between.

Luckily, there are many programs that foster healthy forest management for wildlife. For a land manager, working with a certified forester to address climate resilience, tree diversity, structural diversity, and wildlife elements for other animals usually creates synergy with forest-bee conservation. Snags for raptor nests, for example, are also homes for wood-nesting bees. Piles of logs for salamanders can also protect bumble bee nests. Clear-cutting a monoclonal beech stand that is dying of beech-bark disease can regenerate a healthy tree community that provides forage for bees. Similarly, in the case of ecologically sensitive prescribed burns, most soil-nesting bees can either rapidly recolonize afterward, or are nesting deeply enough to not be impacted and then will be thrilled to see the flush of flowers after the burn. Excessive deer browsing is one of the major threats to forest health and thus forest bee health, so perhaps most important of all are fences and other deer-management protocols to protect regenerating tree seedlings and our delicate and beautiful spring ephemerals and the bees that rely on them.

Although bees are commonly thought of as animals of open places—indeed, one of the best-known lines of poetry about bees is Emily Dickinson's "To make a prairie it takes a clover and one bee," which reinforces this perception—the forests that abut our communities and farmlands play an essential role in sustaining diverse bee populations. Few people have, or perhaps even desire, the opportunity that I've had for close-up exploration of the forest canopy, but all of us can find opportunities to appreciate bees at ground level.

Kass Urban-Mead completed her PhD research at Cornell University before joining Xerces as a pollinator conservation specialist and NRCS partner biologist. She grew up raising 4-H dairy goats in the Hudson Valley.

Leaf litter, rotting wood, and spring flowers support a diverse community of forest bees. Photograph by Liz West.

Careful Observation Unlocks Hidden Connections Between Species

Kevin Burls

The interactions between plants and animals in the landscapes around us are complex, frail, and often hidden from view, but each ecological connection—a caterpillar eating a plant, a flycatcher consuming a butterfly, a bee pollinating a flower—matters. Nowhere is this more apparent than with endangered and extinct species. When a plant or animal is lost, the effects ripple out beyond what we could ever anticipate. As just one example, the extinction of the passenger pigeon (*Ectopistes migratorius*), once so numerous in the United States that miles-wide flocks would darken the sky, may be partially linked to the near-extinction of the American burying beetle (*Nicrophorus americanus*). Burying beetles use the carcasses of dead animals to provide food for their young, a valuable waste-disposal service. Passenger pigeon carcasses were the perfect size for American burying beetles to raise their offspring, so when the passenger pigeons disappeared, many burying beetle populations likely disappeared with them. The species is now hanging on thanks to protection under the Endangered Species Act.

One of the most basic tasks of natural history is documenting these interactions between species—who preys on whom, which insects feed on which plants. Without this knowledge, we

The American burying beetle is still crawling thanks to the Endangered Species Act. Its decline may be tied to the disappearance of the passenger pigeon. Photograph by Bryan E. Reynolds.

Some relationships are unexpected. This carpenter ant is guarding a striped hairstreak caterpillar from predators so that it can gather the honeydew the caterpillar secretes. Photograph by Tom Murray.

may not even notice when species go missing. As Richard Louv, the author of *Last Child in the Woods*, notes: "We cannot protect something we do not love, we cannot love what we do not know, and we cannot know what we do not see."

So much of what we do at Xerces is aimed at this very concept: ensuring that insects and other invertebrates are seen, known, and loved—and, ultimately, protected. Some species, such as the monarch butterfly, are already household names. Others, such as freshwater mussels, which are vital for healthy streams and water filtration, live their lives out of our sight. The invertebrate world is vast and mysterious, and understanding the details of these interactions often starts with a keen eye.

On a summer day in 2011, I was sitting with my wife, Cynthia, in a hot, weedy parking lot in Bishop, a town in the arid Owens Valley east of the Sierra Nevada in California, staring deep down into the leaves of a wild licorice plant (*Glycyrrhiza lepidota*). The activity in the plant was, frankly, chaotic and amazing. There were aphids in large groups, the winged individuals moving around while others sat still as they fed on the plant. There were lady beetles and syrphid fly larvae feeding on the aphids. There were ants scurrying up and down the plant, protecting the aphids while feeding on the sweet honeydew they produce.

Above this activity numerous flying insects were visiting the flowers: bees, flies of all sizes, solitary wasps, and small butterflies with distinctive bright-blue wings shimmering in the sunshine. These male Melissa blues (*Plebejus melissa*) were visiting flowers and chasing females. The females, slightly less flashy on the tops of their wings but with the same beautiful iridescent spots on the undersides, were visiting flowers but also landing on licorice leaves and laying eggs.

Among all this frenetic motion, we noticed a subtler interaction: some

Both male and female Melissa blue butterflies have beautiful iridescent markings on the undersides of their wings. Photograph by Alan Schmierer.

ants would sit on a stem or leaf, twitching their antennae intently rather than dashing up and down the plant. These ants were protecting superbly camouflaged caterpillars of the Melissa blue—stout, bright green, with yellowish lines along their bodies, they would easily be overlooked if not for the ant sentries. These caterpillars, like aphids, produce honeydew; in exchange for this sweet reward the ants will attack anything—including predators like the lady beetles—that come near. The world is a dangerous place for caterpillars, and this beneficial interaction is one way they protect themselves.

Not every animal that feeds on caterpillars is as brightly colored as a lady beetle. Another group of animals, called parasitoids, are common predators of many groups of insects, including moths and butterflies. Parasitoids, mostly wasps and flies, lay their eggs in, on, or near a caterpillar host, and when the eggs hatch, the larvae then feed on the caterpillar *from the inside*. This life cycle typically kills the caterpillar, but not before the parasitoid larva is fully developed, at which point it emerges from the caterpillar (perhaps along with many siblings) to pupate.

Parasitoids are a part of nearly every terrestrial food web, but the interactions are largely hidden from view. Parasitic flies look like many other flies you might meet, although some are slightly hairier. Parasitic wasps, on the other hand, look nothing like the wasps most people are familiar with. They lack the flashy coloration of large, hive-dwelling wasp species, as well as the ability to sting. (A parasitoid wasp has an ovipositor, an egg-laying tube, with which it places eggs inside or on the host; in other wasps, the ovipositor is modified into a stinger.) What's more, many parasitoids are only a fraction of an inch (a few millimeters) in size. This invisibility is compounded by the fact that, once a caterpillar has been parasitized, it tends to look almost identical to an unparasitized individual. It keeps feeding and growing like any other caterpillar until the parasitoid larvae emerge.

Most parasitoids are extremely specialized, feeding as larvae on only a few different species of host animals. They are very diverse—some researchers suggest that because of the number of parasitoids there may be more species of wasps than beetles—and despite their small sizes, they play an outsized ecological role. Some are directly valuable for humans: parasitoid wasps control many common caterpillar crop pests, such as the tomato hornworm (*Manduca quinquemaculata*). Other parasitoid communities keep in check populations of native bark beetles such as the mountain pine beetle (*Dendroctonus ponderosae*), limiting population outbreaks that could be destructive to forests.

Finding a tiny adult parasitic wasp is difficult enough, and even finding adults does not tell you what the parasitoid larvae need as a host. The only way to find out which parasitoids feed on which caterpillars is to raise caterpillars to see what emerges. That means collecting caterpillars, a lot of them, as only a fraction of any population will be parasitized. Which brings us back to the parking lot in Bishop, and why we were staring into the wild licorice plants.

On that hot summer day, Cynthia and I carefully collected caterpillars and a portion of the plants they were on, gently placing them into vials in a climate-controlled cooler. These caterpillars were bound for a laboratory at the University of Nevada, Reno, where they would be raised by Cynthia over the next few weeks as part of a two-year project to document how parasitism

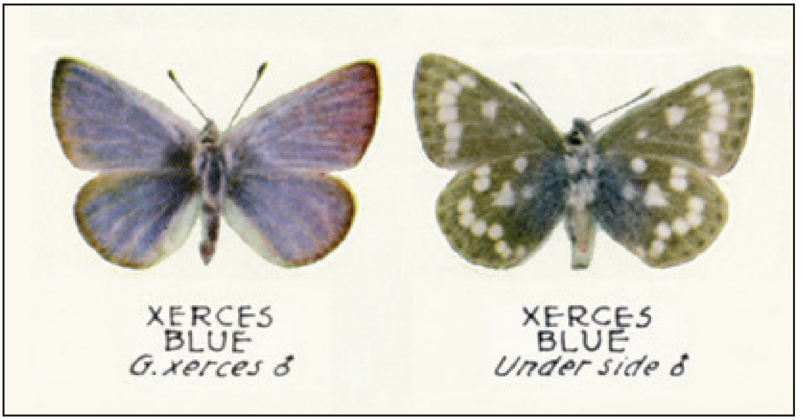
A tomato hornworm caterpillar covered with cocoons of parasitic braconid wasps, which emerged after gradually consuming the caterpillar from the inside. Photograph by Gerald Holmes / Cal Poly San Luis Obispo.

varied across different sites and between native and non-native caterpillar food plants. In our search for parasitoids over the course of the project from 2010 to 2011, Cynthia and I raised more than five hundred caterpillars from six different sites in California and Nevada. When all was said and done, we found a total of five different parasitoid species—two flies and three wasps—feeding on (in) this one species of caterpillar! In 2011, more than 50 percent of caterpillars collected at one location were parasitized. As I mentioned, the world is a dangerous place for a caterpillar.

Among the three wasp species we sent to taxonomists for identification was one in the Braconidae family, identified by Scott Shaw at the University of Wyoming as *Aleiodes cultrarius*. Little is known about this species, but the first individual collected (called the holotype specimen by taxonomists) was reared from a caterpillar of the Xerces blue (*Glaucopsyche xerces*), the only known host for the parasitoid and the first butterfly known to have become extinct in the United States due to human activity. If this parasitoid fed only on Xerces blue caterpillars, one might assume that it also was headed for extinction. But additional specimens of the wasp had been collected in Davis, California, in the 1950s and '60s—at least a decade after the last known Xerces blue was seen, and outside the historic known range of the butterfly—so researchers knew the wasp must also use another butterfly species as a host. In the paper that resulted from our work, Cynthia and I were able to show that not only is *A. cultrarius* also found in Nevada, but that the wasp can raise its young on the Melissa blue butterfly.

Fortunately for the wasp, the Melissa blue is a fairly widespread species across most of the western states and Great Plains. I hope that the wasp

Careful observation of the activity on wild licorice growing at the edge of a parking lot helped reveal fascinating connections between insects. Photograph by Matt Lavin.



Illustrations of the Xerces blue—for which the Xerces Society is named—from John A. Comstock's *Butterflies of California*, published in 1927. Less than two decades later, the butterfly went extinct.

is thriving now, ten years later. Life is hard for wasps, though, just as it is for caterpillars. Parasitoids like *A. cultrarius* need abundant prey, meaning that they need thriving butterfly populations. Worryingly, those are harder to come by, with recent research suggesting that a majority of butterfly species of the western United States are in mild to severe decline, even including widespread species. As adults the wasps also need nectar from flowers, just like butterflies, and places that are free from pesticides. These connections between host and parasitoid are like many other ecological interactions: complex, frail, often hidden from our view.

People often ask, "Why should we bother to protect rare or endangered species?" There are many answers, some more satisfying than others. It can be hard to make a caterpillar glamorous, and perhaps even harder to make a person feel sympathy for an insect that eats a caterpillar from the inside, but we need these animals and their connections, even those we do not know about. Losing the seemingly unremarkable caterpillar of one species might actually mean the loss of an important resource for four or five other parasitoid species.

These important though seldom-noticed creatures are in our gardens, parks, and natural areas alongside butterflies, bumble bees, and other charismatic insects. We can help to protect them from extinction in the same ways we protect other species, by planting native plants and reducing pesticide use. And when you do put plants in, I'd encourage you to sit next to them, and investigate the frenetic activity on the flowers and among the leaves. You never know what you may find.

Kevin Burls is a conservation biologist at Xerces, focused on protecting butterflies across the western United States. Before coming to work at Xerces, Kevin was the integrated pest management educator for the University of Nevada, Reno, from where he holds a PhD in ecology, evolution, and conservation biology.

Ambassadors for a Watery World

Michele Blackburn

Conspicuous, mesmerizing, charismatic: dragonflies are a familiar sight circling the airspace around a water body on a warm summer day, and most people recognize them readily on the wing or perched on vegetation. Their bright, dazzling colors and patterns have long captured the attention of humans. As a result, they are one of the more well-studied groups of insects, with a considerable amount of material published about the behavior and ecology of dragonflies and their near-relatives, damselflies, which collectively form the insect order Odonata (referred to as "odonates"). Despite this, much remains to be understood of dragonflies and damselflies at the species level, particularly details about their lives and their conservation status. The first global assessment of Odonata done by the International Union for Conservation of Nature (released last year) found that one in six of the more than six thousand species evaluated are at risk of extinction as their aquatic and terrestrial habitats are degraded or disappear. Notwithstanding this great effort to understand their status, almost 30 percent of odonates assessed were designated "data deficient," indicating that considerably more attention needs to be focused on this group to understand their needs before they and their habitats can be fully protected.

Dragonflies can be found near just about any water body in North America. Most of the common, widespread species readily observed are habitat gener-

Dragonflies typically rest with their wings spread, and have a clearly noticeable difference in size between their forewings and hindwings. Widow skimmer, photographed by Bryan E. Reynolds.

Damselflies are more slender than dragonflies, but no less colorful. Most will hold their wings over their bodies when perched. Springwater dancer, photographed by Bryan E. Reynolds.

alists and may be found around all types of water, from ponds to roadside ditches. Others are habitat specialists and are associated with specific aquatic habitats; one must know their preferences to locate them. Some are associated with lowland fens, others with montane bogs, and still others with seeps trickling from rocky outcrops. Large streams, too, are not without dragonflies, and a stream species' aquatic stage can be well adapted to the relentless tumult of running waters.

But dragonflies are of two worlds, and it is not uncommon to find them far away from water, near forest edges or in open meadows. Newly emerged adults generally leave their emergence sites to mature and to avoid harassment or predation from other mature dragonflies that are looking for a mate or a meal. Some dragonflies migrate and travel large distances from their breeding and emergence sites. Before we explore that epic phenomenon, let's consider the basics—first, how to distinguish dragonflies from damselflies, and then the life history of dragonflies.

Dragonflies and damselflies are somewhat similar in appearance; after all, they are essentially cousins in the insect world and are often lumped together as "dragonflies" despite some key differences. As "cousins," the two groups are separated into suborders—dragonflies within the Anisoptera, and damselflies within the Zygoptera. (In addition, there is the Anisozygoptera, a relict group that shows a blend of morphological characteristics in common with damselflies and dragonflies. This group is represented by only a handful of living species, none that occur in North America, and is not discussed here.)

At first glance, size separates dragonflies from damselflies, with the former being noticeably more robust. The suborder names, however, allude to what is arguably the most recognizable difference besides their size—their wings. Anisoptera means "unequal wing" and refers to the difference in size between the forewings and hindwings of dragonflies; the forewings are smaller. Zygoptera means "even wing," indicating that the forewings and hindwings

The head of a damselfly is significantly wider than its body, with its eyes widely spaced on the sides of its head. Desert firetail, photographed by Bryan E. Reynolds.

of damselflies are similar in size. In the field (or park, garden, or pond) you'll see that, with some exceptions, dragonflies hold their wings splayed out perpendicular to their bodies while perched, and the difference in wing size is noticeable. In contrast, most damselflies fold their wings together, parallel to their bodies, with their similar-size wings fitting neatly over each other (the exceptions are the spreadwing damselflies, which hold their wings apart and at an angle to their bodies).

Another good distinguishing characteristic to look for is the eye arrangement. Damselfly eyes are well separated to the sides of the head, while dragonfly eyes are bigger and often touch, or nearly so, at the top. Odonates' vision is highly specialized and drives numerous complex tasks and behaviors—selecting a mate, communicating during courtship, recognizing and defending territory, choosing an appropriate site to lay eggs, and catching living prey on the wing with great efficacy, to name a few. Migratory species also use vision to select and maintain their flight along migration routes.

In North America, dragonflies are the more diverse and often the most readily observed of the odonates. They possess a multitude of behaviors and life-history characteristics that dictate where they are found in the landscape, and that can help identify them. Dragonflies are aerial predators, gleaning food, generally other insects, from the air. Two distinct hunting techniques can be observed. Some are "fliers," and are most often found on the wing, whether feeding, patrolling water bodies, or seeking a mate. These are typified by darners and some skimmers, including saddlebags and gliders. Others are "perchers," typified by clubtails and most skimmers, and are generally found on the ground, on vegetation, or on some other substrate, launching from their perches to snatch aerial prey. Fliers will come to rest on a perch or on the ground, but even then these two groups can often be distinguished by their stance; perchers rest with their bodies horizontal, while many fliers hold their bodies vertically.

Although we mostly think of them as aerial insects, the core realm of dragonflies is undeniably water. It is where they begin and spend most of their lives, and where as adults they return to reproduce, laying eggs within or near aquatic habitats. The aquatic stage—known as nymph, naiad, or larva—may last years. The larval stage often passes unobserved by humans, but the nymphs are no less captivating than the adults.

Nymphs appear very different from the adult form, but share the predaceous behavior. Nymphs of all species have a remarkable "prehensile" lip that extends to capture prey. This is unique to nymphs, as it is lost during metamorphosis into the adult stage. Using internal hydrostatic pressure, a nymph can shoot out the labium rather quickly, fast enough to secure such prey as other insects, worms, and even small fish. Some nymphs have flat lower lips armed with spines or hooks to help skewer unsuspecting targets. On others, the lip is rather spoon-shaped, with serrated palps that work to trap and hold prey. In both scenarios, the lip retracts, bringing the meal to the mouth to consume.

The feeding behavior of nymphs may help dictate where a particular dragonfly is found within its habitat. As with adults, some nymphs possess large eyes, which aid in detecting and capturing prey. The eye specializations of dragonfly nymphs are to some extent parallel with their behaviors. For example, nymphs possess different ways of capturing prey depending on the species, with some actively searching for a meal and others lying hidden in wait. Those that actively search are generally visual predators with large, complex eyes, while others, with smaller eyes, may be largely sedentary, using tactile or olfactory cues to detect prey. Cryptic species, those that hide, may be found among vegetation or buried within sediment, with their eyes often the only visible hint that they lie beneath. Some species

A dragonfly's face is dominated by huge compound eyes, which often touch or nearly touch at the top. Blue-faced meadowhawk, photographed by Bryan E. Reynolds.

Damselfly and dragonfly nymphs live underwater. Their remarkable extending mouthparts enable them to catch a range of prey, including small fish. Common green darner, photographed by John Abbott.

do not fall neatly within these groups, and others may employ different feeding modes depending on the environment; for example, if fish are present nymphs that actively hunt may opt for cryptically lying in wait, presumably to avoid predation themselves.

Migration is perhaps one of the most remarkable of insect behaviors, and the long-distance, multi-generational migration of adult dragonflies easily rivals the more familiar migration of the legendary monarch butterfly. The wandering glider (*Pantala flavescens*), for instance, undertakes a journey from India to Africa, twice the distance of the monarch's in North America—and across the open ocean.

Dragonfly migration is more like that of a bird than that of the monarch. They do not descend upon a locale to overwinter in dense groups, but travel to a broad region. In North America, because dragonfly migration is likely dispersed (particularly northbound) and its specific endpoints are unclear, studying the phenomenon has proved to be less direct than, say, tracking a bird with a radio tracker or sticking a tag on a monarch's wing in hopes of recapturing it. Finding a relatively small insect in a vast landscape is like searching for the proverbial needle in a haystack. Another obstacle to studying this behavior in dragonflies is the fact that it largely goes unnoticed. As with the monarch, community science data proved to be a critical tool in understanding the phenomenon, thanks in no small part to the Migratory Dragonfly Partnership, a collaborative effort that was formed a decade ago by the Xerces Society, the U.S. Forest Service International Programs, Odonata Central, Peggy Notebaert Nature Museum, Pronatura Veracruz, and other partners, to better understand North America's dragonfly migration. Unfortunately, due to funding constraints, the MDP is no longer active.

One of the partnership's major initiatives was a community science effort that spanned the migration routes in

Canada, the United States, and Mexico, and trained interested participants to capture information on the phenomenon. In fact, observers posted at Hawk Watch observatories had documented the movements of dragonflies for years, as they appear to use some of the same migratory routes as the birds. The community science data also contributed to work done by researchers with the Smithsonian Conservation Biology Institute, the University of Maryland, and the Vermont Center for Ecostudies that made an important breakthrough in understanding this mysterious behavior using stable isotopes.

Stable isotopes are chemical signatures from hydrogen in water, which vary geographically. Dragonfly nymphs pick up these signatures from the aquatic habitat in which they develop; the signatures become locked into the chitin that forms their bodies and that during metamorphosis eventually becomes the wings of adults. By looking at isotopes in dragonfly wings, the researchers were able to match the signatures with those that occur in precipitation in different areas of North America. While not exact, their research helped to narrow in on geographic origins. They found, for instance, that a common green darner (*Anax junius*) captured in the northern United States had started life in Florida or even further south, in the Caribbean or Mexico.

The complete migratory circuit is multi-generational, with at least three generations of the common green darner involved. Members of the first generation move north in the spring from a broad region that stretches as far south as Central America and Puerto Rico, and lay eggs at their northern destination in the United States and Canada. The second generation emerges and moves south in late summer or fall. Those migrants produce a non-migratory population in the south that eventually gives rise to the next generation of northbound dragonflies, which migrates the following spring.

Adult dragonflies may fly large distances, but they return to water to lay eggs. Common green darners, photographed by Bryan E. Reynolds.

Information collected on migration may prove useful in monitoring the impacts of our changing climate. Dragonflies are ectothermic (commonly referred to as cold-blooded) and have a life history that is profoundly influenced by temperature, which, in part, mediates their migration. In a warming world, dragonflies may leave southern sites earlier for their northward migration, and they may return south later than usual, both of which could alter their life history. That could in turn impact other migrants such as hawks, which may rely in part on this aerial protein source to fuel their own journeys.

Indeed, dragonflies form part of a rich food web, both as predators themselves, and as prey for birds, amphibians, fish, reptiles, and mammals. What's more, they consume mosquitoes and other insects that are pesky to humans, and, by making a dent in those populations, provide us with a valuable service.

Dragonflies are integral to the ecosystems in which they are found. Because they straddle two distinct realms, they can be an excellent tool for understanding both aquatic and terrestrial ecology, and can serve as indicators of the health of, and ambassadors for, these ecosystems. Studying and observing dragonflies (and damselflies as well) can help to make us aware of the persistent threat of habitat degradation and loss in our environment; if we heed these warnings, we can initiate change before even more of these colorful and valuable species are at risk of extinction.

Michele Blackburn is a conservation biologist at Xerces and provides research and mapping support to inform conservation programs for at-risk invertebrates. She is equally at home paddling a kayak through aquatic habitats as she is studying the life within these vital ecosystems.

Dragonflies are an indicator of the health of both aquatic and terrestrial habitats. Spangled skimmer, photographed by Bryan E. Reynolds.

STAFF PROFILE

Logan Lauvray, Accounting and Data Manager

What got you interested in insects? As a child I spent a lot of time playing outside. I was lucky to be in a rural part of Ohio where I could go exploring in the nearby creek and in the adjacent woods—both of which held a bounty of small wildlife. I remember capturing lightning bugs in glass jars during summer evenings to watch them more closely.

What made you want to work at Xerces? I first applied for a part-time accounting job here a decade and a half ago. It was a much smaller organization then, and the scope of the position was far less complex. I was attracted by the unique mission that Xerces had, focused exclusively on invertebrates, and its commitment to finding solutions to the multiple environmental issues we are facing, including—even back then—that Xerces was addressing our need to dramatically reduce the use of pesticides.

What's your favorite place to visit? I have been fortunate to get to visit and backpack in numerous national parks here in the United States including Yellowstone, Grand Tetons, Glacier, and Yosemite. Over the last several years I have been going with my husband to the Olympic National Park for week-long backpacking trips. The trees are spectacular—we have seen some of the largest western hemlocks and Sitka spruce trees in the continental United States—and there's great wildlife (elk, black bear, marmots, and grouse as well as some terrific butterflies). In addition, the creeks, rivers, and lakes that we encounter are all so clear and beautiful—and all of this is less than a four-hour drive from our house.

Who is (or was) your environmental hero? Bob Pyle has been an environmental hero of mine for at least the last fifteen years, in part because of the wonderful conservation organization that he helped found; but just as much for his writing and the practical changes he highlights and encourages.

Wangari Maathai has also been my hero for nearly two decades. She founded the Green Belt Movement in Africa and was the first African woman to win the Nobel Peace Prize. I learned about her through my work in community urban forestry, and was hugely impressed with what she accomplished and the work that she championed.

PARTNER SPOTLIGHT

LandPaths

LandPaths is an environmental education and conservation organization based in Santa Rosa, California. Its mission is to foster a love of the land in Sonoma County, a task it approaches with a deep commitment to equity in the outdoors. As stated on its website, "we believe everyone should have access to the awe and inspiration of nature."

The organization's core work consists of outdoor activities, nature camps, and land stewardship, conducted in both Spanish and English. The Branching Out Conservation for Everyone program connects people with nature by offering hikes, birdwatching, and similar activities from which participants gain physical and emotional benefits.

Growing Community With Nature provides opportunities to join one-off or ongoing stewardship projects such as tree planting, weed pulling, or trail maintenance at local greenspaces and reserves. These activities benefit nature while building community resilience.

The Rooting Youth in Nature program focuses on getting children and teens outside, whether that is floating down the Russian River in a kayak, engaging in a school-based environmental education activity, or joining a family-oriented book reading in a garden.

LandPaths also runs summer camps. The Owl Camp features a series of themed weeks to explore nature "the old-fashioned way"—hiking, building forts, playing in creeks, doing arts and crafts, learning curiosity.

It was LandPaths' dedication to equity and its work to connect people with nature that led Xerces to seek out a partnership as we developed *X Kids*, our activity book to help children discover invertebrates. Resources for children were a new area for us, and LandPaths staff offered knowledge and experience that helped shape the activities.

The book was reviewed by several of their education staff and the activities were kid-tested at their summer camps. The resulting changes made the activities better fit learning targets and helped ensure that the program would be accessible and culturally appropriate. LandPaths also provided translation services.

For more information about LandPaths, visit landpaths.org.

Photograph courtesy LandPaths.

XERCES NEWS

A Major Victory for California's Insects

A multi-year campaign to protect four species of bumble bees in California reached a successful conclusion when courts in California upheld the state's decision to allow protection of bumble bees under the California Endangered Species Act. The four species—western, Franklin's, Suckley cuckoo, and Crotch's bumble bees—have declined extensively from their historic ranges and urgently need the protection that CESA can provide.

The Xerces Society submitted a petition to the California Fish and Game Commission requesting protection for the four species in 2018. We were joined on the petition by the Center for Food Safety and Defenders of Wildlife. In June 2019, the Commission voted to make the bumble bees "candidate species" and thus begin a one-year process to determine whether they qualify for endangered status in the state.

Unfortunately, a consortium of large commercial agricultural commodity and pesticide groups, led by the Almond Alliance, sued the State of California, trying to make the case that insects could not be protected under CESA. The initial case in county court decided in favor of the commodity groups. That ruling was successfully appealed by the State of California, the Xerces Society, and partners, a decision that was upheld when the commodity groups took the case to the Supreme Court of California, which ruled that the state can protect insects.

Crotch's bumble bee (*Bombus crotchii*). Photograph by the Xerces Society / Stephanie McKnight.

This is a huge win for bumble bees and other invertebrates facing imperilment in California. If the decision had gone to other way, CESA—legislation intended to provide protection to California's most needy wildlife—would have excluded around 80 percent of the state's animal diversity.

California cannot maintain its exceptional biodiversity or sustain its agricultural systems without protecting its native pollinators, whose loss could have far-ranging ecological consequences. Other terrestrial invertebrates facing extinction, such as the monarch butterfly, are also now eligible for protection under CESA. Protecting the diversity of insects in California will help to ensure that insects can continue to provide vital ecosystem services.

Challenging Pesticide Spraying on Western Rangelands

For decades the USDA Animal and Plant Health Inspection Service (APHIS) has overseen and funded the spraying of toxic insecticides across public rangelands in the West. The main insecticide sprayed is diflubenzuron, which kills a wide variety of juvenile insects both on the rangelands and in streams and rivers that flow through these areas.

In any given year millions of acres can be sprayed, killing hundreds of millions of native grasshoppers that play a critical role in food webs. Numerous grassland birds, including at-risk species such as sage-grouse, Swainson's hawk, long-billed curlew, and sage thrasher, rely on grasshoppers for food, as do many mammals and reptiles.

Western rangelands are also home to hundreds of species of native bees, including the declining western bumble bee, and form a large portion of the breeding range of the monarch butterfly's western population.

Xerces has consistently reached out to APHIS over several years, both through meetings and detailed comment letters, to encourage more ecologically sound management techniques. Regrettably, our pleas have fallen on deaf ears. APHIS's 2022 program recycled the template it has used for twenty years, and lacked even minor mitigations to address the issues we've raised. In the face of such intransigence, Xerces, represented by Advocates for the West and joined by the Center for Biological Diversity, filed a lawsuit in May, alleging violations of the National Environmental Policy Act and the Endangered Species Act. The lawsuit is ongoing.

This past year Xerces made significant progress engaging with the Bureau of Land Management and the U. S. Fish and Wildlife Service—federal agencies involved with the APHIS pesticides program. Most notably, the Idaho BLM office halted insecticide applications except within one mile of croplands at risk from severe grasshopper or Mormon cricket pressure. This action protected 4.6 million acres of public lands.

Grasshoppers are an important component of the food web of grassland ecosystems. Photograph by Bryan E. Reynolds.

White checkered-skipper (*Pyrgus albescens*) nectaring on mist flower. Photograph by Bryan E. Reynolds.

Your Legacy for Invertebrates

A charitable bequest is one of the simplest ways to provide continuing support to the Xerces Society beyond your lifetime. Your gift will have a lasting impact on the conservation of essential invertebrates and help preserve these creatures for future generations.

We highly recommend that you discuss your planned giving options with your professional advisor in order to choose a gift that works best for you and your family. If you have questions or would like to inform us of your plans, please complete our online planned giving form at xerces.org/donate/planned-giving or send an email to membership@xerces.org.

Thank you for considering Xerces in your planning.

Bee City USA Marks its Tenth Anniversary

Bee City USA was founded in 2012. It was the brainchild of Phyllis Stiles, who developed the framework and requirements—habitat creation, protection from pesticides, and outreach to the community—and, with the support of a small group of other local bee enthusiasts, took the idea to the city council of her hometown, Asheville, North Carolina. In 2018, as Phyl was looking toward retirement she wanted Bee City and its sister program, Bee Campus, to be in safe hands, and Xerces took over responsibility for administering them.

As we mark Bee City's tenth anniversary, the network of communities has passed the three hundred mark and reached forty-five states. The momentum continues and every month we add new cities and campuses, which must meet minimum requirements to become affiliates. While Xerces staff support the affiliates and provide resources to assist them, everything that is achieved is due to the creativity and hard work of the communities. Their

For ten years, Bee City USA has united communities around a shared desire to help pollinators. Photograph courtesy Bee City USA–Talent.

efforts accomplished a great deal in 2021, the last year for which affiliate reporting has been completed.

Affiliates created more than 1,150 acres of new habitat, ranging from community gardens and street landscaping to meadows and prairies. In addition, many of them were able to discontinue pesticide use altogether, implementing non-chemical pest-prevention and management methods on city or campus grounds. Others eliminated the use of neonicotinoid insecticides or shifted to using only organic products, and 10 percent stopped cosmetic pesticide use.

More than sixteen hundred events were hosted by affiliates in 2021, reaching upwards of 155,000 people. The range of events reflects great creativity: webinars and online gatherings, masked and distanced garden tours, virtual classes and book readings, self-led education activities, crowdsourced pollinator surveys using phone apps, tabling at farmers markets, quiz nights, parade floats, and much more.

Thank you to the individuals and communities who contribute so much to helping pollinators. What has been achieved is astonishing, and we are excited about the possibilities for the next ten years of Bee City USA. We look forward to continuing to support the affiliates' incredible work.

Harmful Pesticides Found in Milkweed Plants at Nurseries

Butterfly gardening is a popular pastime. Sadly, a recently published study undertaken by Xerces scientists and researchers from the University of Nevada, Reno and the University of Tennessee shows that gardeners can't necessarily trust the plants in their local garden center.

The study, published in *Biological Conservation* in September, found harmful levels of pesticides in milkweed plants purchased from retail nurseries across the United States. Pesticides were found in all plants tested, raising alarms for monarch butterfly conservation efforts that rely on planting milkweed sourced from commercial nurseries.

Researchers gathered 235 milkweed leaf samples from retail nurseries across fifteen states and tested them for pesticides. In total, sixty-one different pesticides were found, with an average of twelve per plant and as many as twenty-eight. Only nine of the sixty-one chemicals found have been tested to understand their effects on monarchs, which means the researchers couldn't fully assess the toxic load carried by these plants. Even so, 38 percent of the samples had residue levels that could harm monarchs' ability to migrate and forage.

Shockingly, milkweed plants labeled as "wildlife-friendly" did not have fewer pesticides in or on their leaves. The study's findings highlight the need for nurseries to ensure that pollinator-friendly plants are also pollinator-safe.

If you are a monarch enthusiast and are wondering what you can do, Aimée Code, director of the Pesticide Program at the Xerces Society and a coauthor of the study, offers the following advice. Consumers can let their nurseries know that they want plants that are free from harmful pesticides. (Visit the Bee-Safe Nursery Plants pages on our website for more information.) Gardeners can take steps to reduce pesticide exposure, including discarding the soil before planting, as it may be contaminated; covering new plants during the first year to deter insects seeking nectar; watering heavily; and, of course, avoiding their own use of pesticide chemicals.

WINGS, Fall 2022 **Volume 45, Number 2**

Wings is published twice a year by the Xerces Society, an international, donor-supported nonprofit organization dedicated to protecting the natural world by conserving invertebrates and their habitat. A Xerces Society membership costs $35 per year (tax-deductible) and includes a subscription to *Wings*; the magazine can also be downloaded from our website as a PDF.

For information about membership and about our conservation programs for native pollinators, endangered species, and aquatic invertebrates, as well as our efforts to reduce the impacts of pesticides, please visit our website.

 Xerces Society Executive Director: Scott Black. *Editors*: Scott Black, John Laursen, and Matthew Shepherd. *Design and Production*: John Laursen. Printed on recycled paper.

The Xerces Society for Invertebrate Conservation

xerces.org toll-free 855-232-6639

The arrowhead spiketail is a dragonfly of the eastern United States. Its nymphs, like this one, live in spring-fed forest streams. Photograph by John Abbott.

The Xerces Society for Invertebrate Conservation

628 Northeast Broadway, Suite 200, Portland, OR 97232

A $35 per year Xerces Society membership includes a subscription to *Wings*.

On the cover: Although we think of dragonflies as large insects, some are quite small—including the eastern amberwing, just an inch long. Photograph by Bryan E. Reynolds.

XERCES SOCIETY
for Invertebrate Conservation