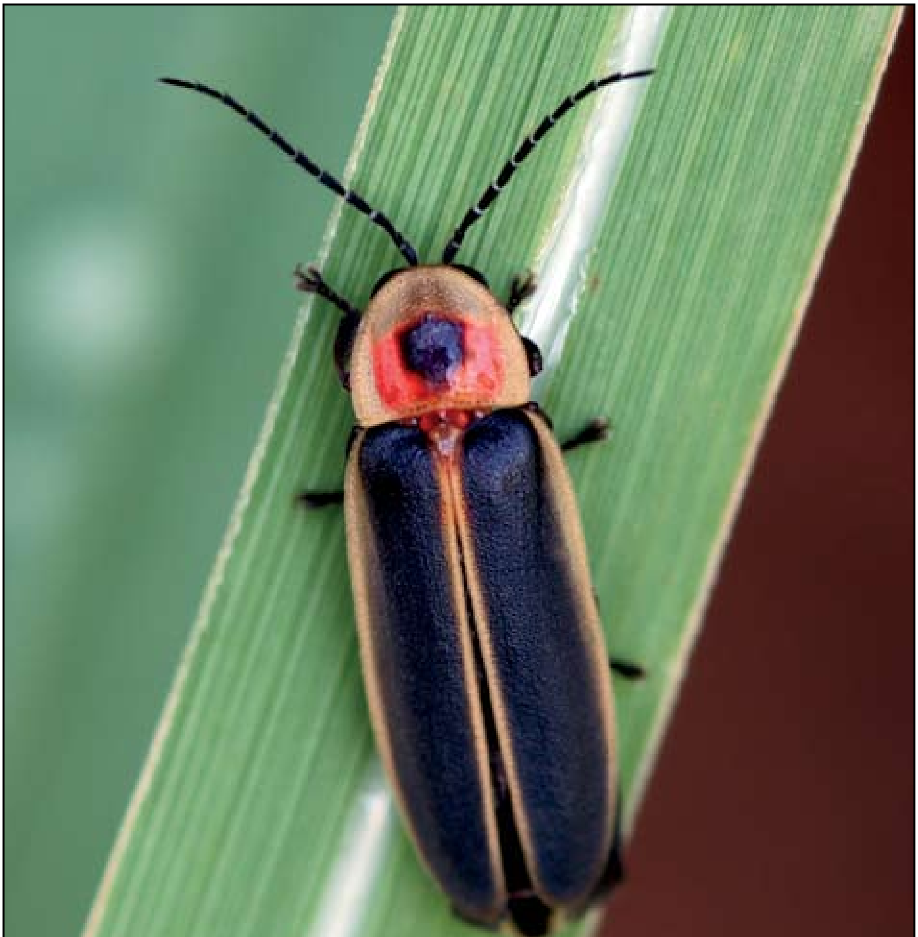
WINGS

ESSAYS ON INVERTEBRATE CONSERVATION



THE XERCES SOCIETY **FALL 2012**

CONTENTS

Over the next year or so, we will be making a series of changes to *Wings*, which we hope will add to your enjoyment of the magazine. In this issue we introduce a new feature, an opening editorial comment from the Xerces Society's executive director.

Happy Birthday, *Silent Spring*

Scott Hoffman Black

This fall sees two important anniversaries for environmental protection. It is fifty years since *Silent Spring* was first published and forty since the U. S. Clean Water Act was signed into law.

Rarely does a book have as large an impact on society as that which *Silent Spring* has had. Rachel Carson's book examined the harmful effects of the unrestricted use of chemical pesticides. Initially released as a series of articles in the *New Yorker* magazine during the summer of 1962, *Silent Spring* was published as a single volume in September of that year.

Silent Spring was derided by people in the chemical industry and they spent a considerable amount of effort trying to stop people from hearing Carson's message. They first tried to portray her as an "hysterical woman," and when that did not work they tried to discredit the science upon which *Silent Spring* was based. They even went so far as to pull advertising from news programming where the book was being discussed.

Both Carson and her book weathered the criticisms: *Silent Spring* came to the attention of millions of Americans, and became a catalyst for change. The Kennedy administration ordered a federal investigation of Rachel Carson's claims, which resulted in big changes in the government regulation of toxic pollutants. *Silent Spring* led to the banning of DDT and, some say, to the creation of the U. S. Environmental Protection Agency.

Half a century after the publication of *Silent Spring* and the consequent introduction of government regulation of toxic chemicals, nectar-feeding insects are still threatened by the widespread use of insecticides. Southern dogface butterfly (*Zerene cesonia*), photographed by Bryan E. Reynolds.

The Clean Water Act may have received less public acclaim than *Silent Spring*, but it has been no less influential over the health of the country's lakes, rivers, and streams, as well as its coastal waters. The Act was signed into law forty years ago in response to a public that was starting to understand the impact of chemical pollutants on their lives. At that time, industrial waste and untreated sewage were routinely dumped without concern. Two-thirds of U. S. lakes, rivers, and coastal waters were unsafe for fishing or swimming. The poor health of the nation's rivers was dramatically illustrated by well-documented accounts of some that burst into flames! The Act was intended to change this, and directed the EPA to evaluate, restore, and maintain the chemical, physical, and biological integrity of U. S. waters.

As with *Silent Spring*, the Clean Water Act encountered resistance from powerful business interests, but since it was enacted, fish have returned to many rivers that were once all but lifeless. Of course, not many people talk about how this law has benefited the invertebrates at the base of the food chain, but you can imagine that the return of fish is intimately wrapped up with the recovery of invertebrate food sources.

Unfortunately, despite all the actions taken because of *Silent Spring* and Clean Water Act regulations, the use of toxic pesticides has actually gone up. Pesticide use on farms alone has doubled, to 1.1 billion pounds a year. Tens of thousands of acres of public lands are sprayed each year to control native grasshoppers, often with little regard for the presence of other insects or water bodies. We also use millions of pounds of pesticides in our parks and gardens—often more pesticides per acre than on farms—all in the quest for unblemished lawns or aphid-free roses.

In setting safety levels for pesticides, the government considers not only toxicity but also the economic benefits, pitting agricultural production against the impacts on humans and wildlife. We have banned certain pesticides, such as DDT, but often have replaced them with narrow-spectrum pesticides of even higher toxicity. For example, one emerging concern is over a class of insecticides called "neonicotinoids," which many people have linked to honey bee die-offs. The Xerces Society recently released a report that details negative impacts of neonicotinoids on pollinators. Many neonicotinoid pesticides are sold to homeowners for use on lawns and gardens; they lack any mention of the risks to bees, and the manufacturer-recommended application rates are up to 120 times as high as rates approved for agricultural crops. As Vice President Al Gore said in his introduction to the 1994 edition of *Silent Spring*, "The legal, regulatory, and political system has failed to respond adequately."

Both *Silent Spring* and the Clean Water Act have had enduring legacies, although unfortunately, neither has been wholly successful at curbing chemical pollution. In the last chapter of *Silent Spring*, Rachel Carson makes an analogy to Robert Frost's famous poem "The Road Not Taken," but points out that, unlike the roads in the poem, our choice has wide-ranging consequences. One fork is "deceptively easy," but "at the end lies disaster"; the other "offers our last, our only chance to reach a destination that assures the preservation of our Earth." Which road will you take?

Life at the Speed of Light

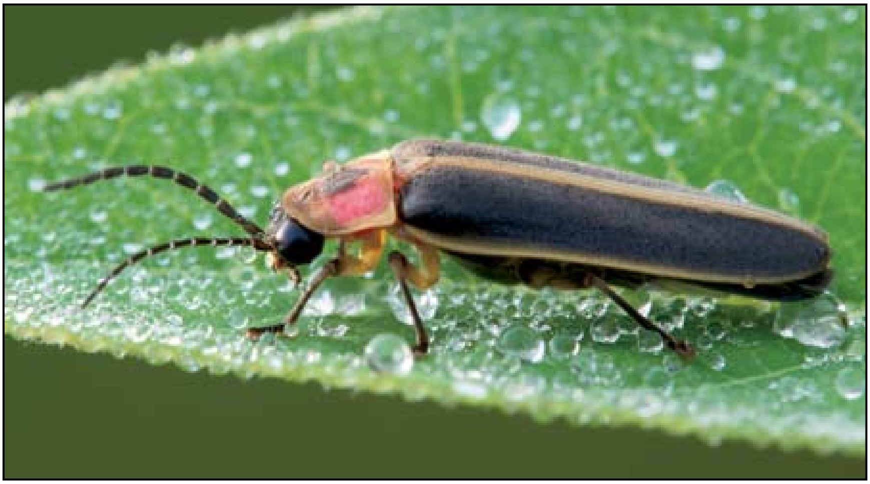
Eric Mader

Those of us lucky enough to have lived among fireflies have been conscious, at one time or another, of the sense of mystery they add to our lives. Moments that might otherwise be totally forgettable seem to take on a deeper resonance when they happen against the impermanent display of fireflies living out their own complex life cycles, plainly visible through that improbable flash of light.

In those flashes fireflies live and die. They find a mate, use mimicry and deceit to kill, and confound attempts by human scientists to understand them. Their flashing pre-dates the existence of humans by more than twenty million years, yet lends itself to such modern medical breakthroughs as advanced screening tests for cancer and cystic fibrosis. They stalk the damp, weedy undergrowth of contemporary human landscapes, but do so in a world of mowing machines, insecticides, street lights, and changing weather patterns. How long they will continue to flash is a question that more and more people have begun to ask.

Fireflies are neither flies, nor, as the alternate common name "lightning bug" might suggest, true bugs. Rather, they belong to the beetle family Lampyridae, comprising five subfamilies that include roughly two thousand

Catching fireflies and watching their seemingly magical flashing has been a part of childhood for millions of people. Photograph by Steven David Johnson.



Most research into fireflies has focused on their ability to flash; we know little about the natural history of some species. Eastern firefly (*Photinus pyralis*); photograph copyright iStockphoto/harmonia101.

species worldwide, primarily in Europe, Asia, and the Americas. There are around two hundred species in North America.

For all that we do know about fireflies, it is striking that we actually know very little. Widespread nocturnal species have attracted the most scientific attention, but research has focused largely on bioluminescence chemistry rather than ecology. Diurnal species, which lack light-producing organs as adults, have been largely overlooked.

What *is* known is that fireflies tend to be most associated with humid grasslands and forests. A number of the most well-known species also rely on stream sides and wetland edges for habitat, damp places that support plenty of prey. A few species in Asia are even fully aquatic, breathing through tracheal gills and lurking on the bottoms of rice paddies.

Firefly adults of any given species tend to emerge at the same time each year. Spectacular mass emergences, with tens of thousands of individuals flashing in unison, are sometimes reported in the jungles of the Philippines and Malaysia, and in the Great Smoky Mountains of the United States.

During their adult lives fireflies will find mates and reproduce. Females lay their eggs in the soil, typically under the protective cover of thick forest leaf litter, decaying logs, or grassy thatch. The larvae hatch days to weeks later, and patrol the undergrowth for soft-bodied prey. Slugs and snails are a well-documented preferred food resource, making these predatory larvae important for farm and garden pest control.

As larvae, nearly all firefly species generate a weak greenish glow from a "photic" light-producing organ in their abdomens, likely as a warning to their own predators that they have protective chemicals in their bodies that render them toxic. Among diurnal species, this light-producing organ is lost during the transformation to adulthood, although the chemical defenses may or may not remain.

This is the standard narrative about the ecology of fireflies, based upon scant observations by the few people who have tried to follow them. The truth is, however, that, for most firefly species, how and where they live the majority of their non-flashing lives remains a mystery. Even basic field monitoring is often challenged by close physical similarities between species, requiring dissection and an examination of the internal organs to reach reliable species-level identification.

A more basic approach to firefly identification, though, is simply to watch them flash. For more than a century it has been recognized that the adult flashing represents a kind of courtship behavior. Understand the flashing, and perhaps you could understand which species is doing it: this was the discovery

Male fireflies flash on and off as they fly, with each species having a distinctive pattern to the color, frequency, and sequence of its flashes. Time-lapse photograph of fireflies in the Great Smoky Mountains by Judd Patterson.

of Frank McDermott, a self-taught Delaware entomologist, who, in 1911, recognized that among American fireflies, the color, frequency, and sequence of flashes are unique to individual species. Simply by watching and learning the various flash patterns, a person could identify distant fireflies to species level across a meadow. At least, this was the case with male fireflies.

Female fireflies, on the other hand, did not seem to exhibit any differences in their flash patterns. Perched on tall blades of grass or on low-hanging tree branches, female fireflies respond to the elaborate flashing of males flying in their vicinity with a single, solitary, identical flash. How could a male firefly identify a female of his own kind?

Enter Dr. James Lloyd of the University of Florida, who in the 1960s cracked the code with the discovery that, while females do respond with just a single flash, those of different species time that response differently relative to the male's flash pattern: females wait for a certain precise duration before responding to a male's signal. By measuring that response time, a careful observer can recognize the female's identity.

Or so it would seem.

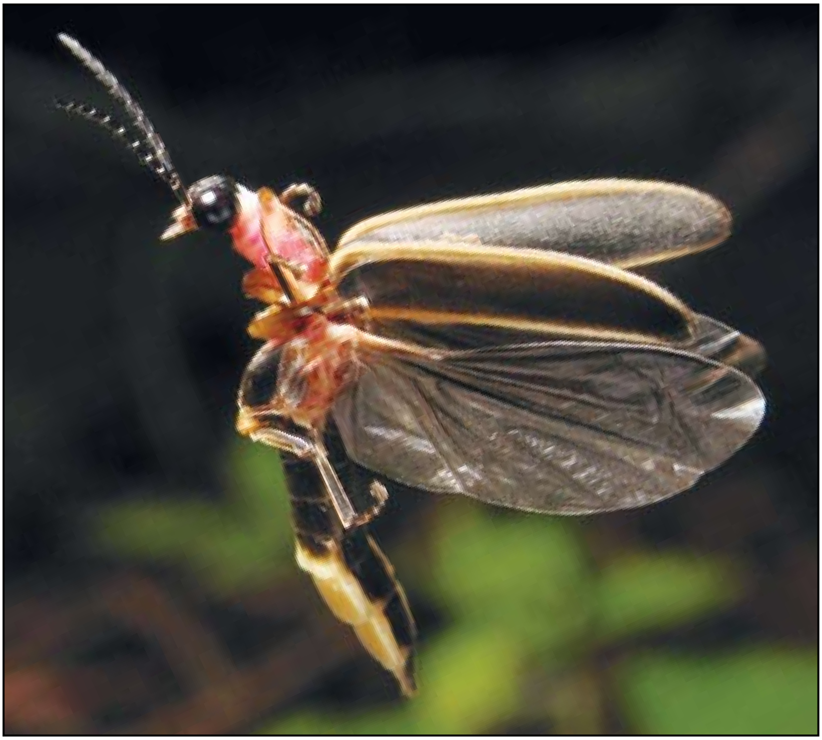
Females of the genus *Photuris* confound this type of simple response-time identification by often mimicking the flash timing of females in the genus *Photinus*. Through this mimicry *Photuris* females are able to lure unsuspecting *Photinus* males, whom they kill and consume. *Photuris* females can switch response patterns, either to find a suitable mate of their own species or to capture *Photinus* prey.

And those *Photinus* males aren't simply a handy late-night meal. Among fireflies several groups produce a collection of steroids called "lucibufagins," and species in the genus *Photinus* belong to one of these groups. For the most part, predators such as birds seem to quickly taste lucibufagins—which are present in the blood of some fireflies at high concentrations—and immediately reject them as a possible food, often by simply vomiting them up. Spiders and other predators with highly developed chemical receptors usually avoid them altogether.

Which brings us back to the *Photuris* females, who, as it turns out, cannot produce their own lucibufagin chemical defense. Rather, by attracting *Photinus* males with some simple trickery and consuming them, they are able to acquire their own blood concentrations of lucibufagins, and, perhaps more important, they can also bequeath their eggs a protective dose.

While lucibufagins are important in the ecology of lampyrids, two other chemicals, luciferin, a light-emitting biological pigment, and the enzyme luciferase have been the focus of much greater scientific attention. (Although not chemically related, these three compounds share the root word *lucifer,* from the Latin word for "light-bringing.")

In fireflies, both luciferin and luciferase are present in the photic organ on the underside of the abdomen. To generate light, these combine with oxygen (carried to the photic organ through tracheae, abdominal breathing tubes) to emit a photon—an elementary particle of light. After the reaction, the various component parts revert to their original state, allowing the firefly to flash again and again while exerting almost no energy.



In flight, the luminescent segments of a male firefly's abdomen are clearly exposed. Females will flash their response from a perch on vegetation. Common eastern firefly (*Photinus pyralis*), photographed by Terry Priest.

The light produced is accompanied by virtually no heat, with more than 90 percent of the chemical reaction released as light. While the chemical process is well understood, uncertainty remains about how the fireflies actually control the flashing. Most researchers speculate that they control the oxygen intake of their tracheae—their breathing, as it were—to initiate the reaction process.

In addition to the quiet awe that bioluminescence typically inspires in anyone seeing it, the fireflies' flash is also the foundation of new medical imaging technology to track the progression of disease in humans. Using firefly luciferin and luciferase injected into cancer cells, for example, medical researchers have been able to track the growth of tumors using specialized cameras, a preferable alternative to more-invasive biopsies. Related research combines the bioluminescent imaging of cancer cells with the treatment of those same cells by chemical agents that render them light-sensitive; the goal is to cause the cancer cells to self-destruct by making them both simultaneously light-producing and susceptible to death by light exposure. This new technology in effect helps the body generate its own light within internal malignancies that external light sources cannot penetrate.

Bioluminescent imaging is increasingly being used to track other infectious diseases, to track hormone production in the body, and even to monitor for the presence of disease-causing bacteria in food products. And bioluminescence technology is now being proposed for a dizzying array of serious and not-so-serious purposes, from genetically altered glow-in-the-dark trees that could replace streetlights, to biotech potato crops that glow when they need water, to luminescent pet rabbits. Each of these uses raises complex and far-reaching questions.

One such question has been simply how to meet the growing demand for raw luciferin and luciferase. Until recently most of this demand was met by pharmaceutical companies paying bounties on wild-collected fireflies, primarily in rural Appalachian communities. No one is certain what the ecological toll of these collections may have been, but local newspaper stories from as recently as the 1990s describe people making up to $3,000 in a single season on fireflies (with the insects priced at a penny apiece).

Researchers now know how to artificially synthesize the luminescent proteins, and organized firefly collecting is no longer publicly advertised, although several pharmaceutical supply companies still offer pure firefly-derived chemicals, as well as whole preserved fireflies for sale. Where these specimens come from is neither publicly known nor legally regulated.

All of this leads us to the greatest firefly mystery of all: from a conservation standpoint, just how are they doing in the world today? Anecdotally, their numbers are down. Ask anyone who grew up around fireflies and they will tell you that they simply do not appear in the numbers that they used to. But, from a global perspective, how can anyone really know?

Certainly, like other wildlife, fireflies have confronted an unprecedented loss of habitat worldwide since the Industrial Revolution and the corresponding industrialization of agriculture. In the United States, such native firefly habitats as the eastern tallgrass prairie and eastern hardwood forests have been largely converted to other land uses. Land not already paved over or cultivated for crops—lawns and roadside verges, for instance—is often subject to mowing and insecticide spraying. The former reduces habitat for breeding, while the toxic residues of the latter may harm fireflies either directly, or, by reducing populations of their prey, indirectly.

Along with these somewhat obvious threats, the effects of light pollution and climate change raise additional concerns. If you require darkness to find a mate, and you have a life history that is closely linked to stable annual weather cycles, the world may increasingly seem to be a less hospitable place. As with so much surrounding fireflies, we understand only part of their story and the specific challenges they face. For how much they contribute to human science—and for the sense of wonder that they bring to our world—it's a shame that their last great mystery could be the question of their own survival.

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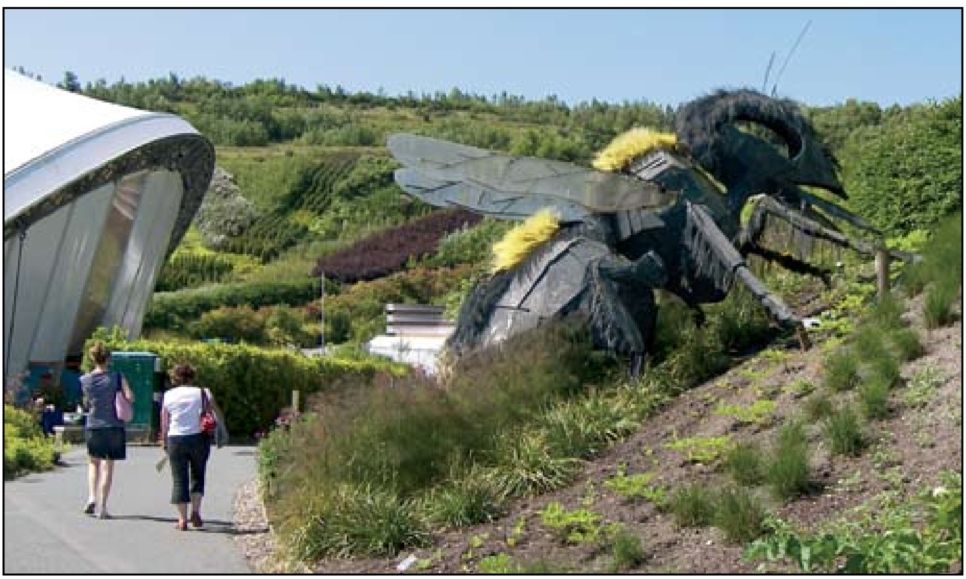
Six-Legged Sojourns: Insect-Based Recreation and Tourism

Raynald Harvey Lemelin

People are often surprised when they hear about my research into human interactions with insects in recreational and tourism settings. Some have even said that this type of research is so strange that I should stick to polar bears, another of my scientific interests. While I am no longer surprised by such comments, I usually point out that our connections to insects are much closer than most people think, with millions of enthusiasts raising bees as a hobby, keeping insects as pets, transforming their yards with butterfly gardens or dragonfly ponds, or deliberately seeking out insects by visiting live flight displays. I also note that while, yes, polar bears are "cool" predators, on the evolutionary scale dragonflies are way cooler; among the earth's oldest and most efficient predators, dragonflies have been flying and capturing prey for millions of years, long before the first bear ever appeared.

In addition to my research interests, my family's recreation activities often center on insects. Along with participating in insect surveys, hosting two insect symposiums, and providing native plants for insects in our yard, we have raised several generations of monarch



Insects hold an increasingly significant place in recreation and art. Bumble bee sculpture at the Eden Project in southwest England, photographed by Colin Boylett.

(*Danaus plexippus*) and American lady (*Vanessa virginiensis*) butterflies. Now my engagement with insects and recreation has been taken to a new level by the process of editing a book, *The Role of Insects in Recreation and Tourism*, to be published by Cambridge University Press in early 2013. This work has revealed to me that the field of human-insect interactions is large and diversified. For the sake of clarity, I will focus here on the current popularity of three charismatic micro-faunas—bees, dragonflies, and butterflies—although our infatuation with insects goes back a long time and extends to virtually all insect groups.

Insects have provided inspiration to all manner of people over the centuries. Napoleon Bonaparte, for example, replaced the fleur-de-Lys with bees as a symbol of France. In literature, Alfred Lord Tennyson's poems feature insect references, and Sylvia Plath and Ted Hughes exchanged a series of poems about honey bees. Nikolai Rimsky-Korsakov's *Flight of the Bumblebee* is probably the best-known insect-inspired musical composition, and Vincent van Gogh and Pablo Picasso both included insects in some works. Today, fabric motifs, paintings, sculpture, jewelry, furniture, household items, toys, and tattoos often incorporate insects. In science and engineering, ornithopters (radio-controlled aircraft with flapping wings) mimic dragonflies, and, as early as the 1970s, the CIA created an "insectothopter," a life-sized robotic dragonfly. Even architects have been influenced: termite mounds inspired the exoskeletal skyscraper designed for the South Korean city of Cheongju.

The link between insects and leisure may at first glance appear dubious; travelers, after all, go to great means to avoid such insects as cockroaches, mosquitoes, and bed bugs. But the figures suggest otherwise: each year millions of people around the world visit hundreds of insectariums and butterfly pavilions, attend dozens of insect-based festivals and special events, and volunteer for citizen-science projects dedicated to insects. For example, crowds greater than two hundred thousand flocked to Pestival (described on its web site as "a mobile arts festival examining insect-human interactivity") in 2009, when its last major event was held at London's Southbank Centre. The glow-worm caves of Australia and New Zealand are a destination for sixty-three thousand visitors each year, a number that Michael Hall, one of the leading figures in tourism research, suggests is comparable to whale-watching operations in Hervey Bay, Australia. In Japan, it is estimated that there are at least three hundred thousand fans of beetle breeding who spend millions of dollars on insects, special events, and entomological accessories. Closer to home, thousands of visitors travel each year to rural areas in North America to watch fireflies. And countless gardeners have collectively spent millions of dollars modifying their home landscapes to create insect habitat, and planting flowers to attract butterflies and other pollinators.

Bees have become the focus of vacation trips, including visits to zoos, pollinator parks, and beekeeping museums throughout North and South America, Europe, and Australia. Tourists journey to the Sundarbans forest (straddling the border between India and Bangladesh) to spend time with Mowali honey gatherers, or to Nepal to join the Rai on their

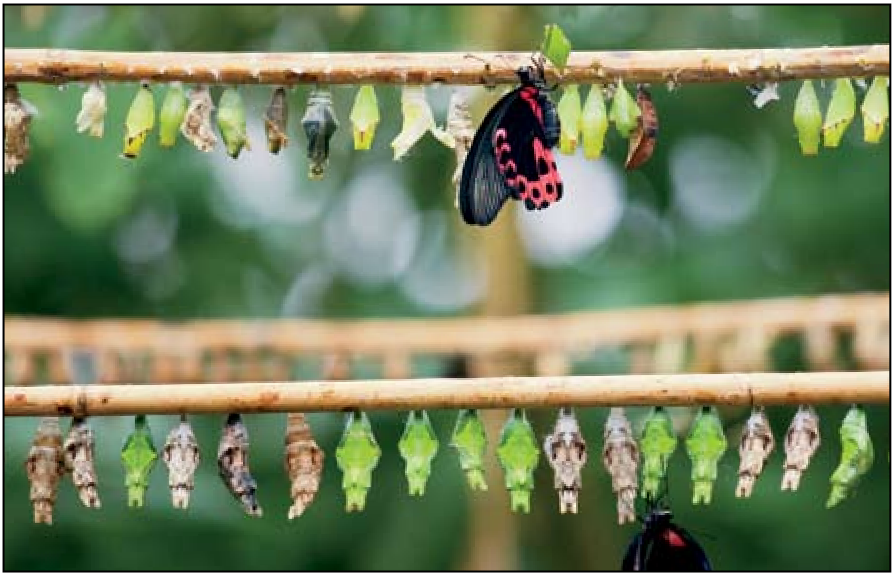
Live butterfly displays have become popular attractions in many places; this one is in Singapore's Changi Airport. Photograph copyright iStockphoto/tc397.

excursions in search of the honey of the giant honey bee (*Apis dorsata*). One of the most famous tourism destinations to feature bees may be the Royal York Hotel in Toronto, Canada. Here, guests learn about the art of beekeeping and get a chance to taste specialty dishes, tea, and cocktails featuring honey from the hotel's rooftop hives.

As with beetles, fascination with dragonflies as a pastime is probably most developed in Japan. With hundreds of dragonfly ponds and numerous sanctuaries, including the Honmoku Citizens Park in Yokohama, the Dragonfly Kingdom in Nakamura (the world's first dragonfly nature preserve and museum), and the Conservation Area at Okegaya-numa, Japanese enthusiasts have the opportunity to practice and perfect their skills. In other countries, people may enjoy dragonflies more as a part of the natural landscape. Visitors to Wicken Fen National Nature Reserve in Cambridgeshire, England, have opportunities to see and learn about these insects, while the National Botanical Gardens in Pietermaritzburg, South Africa, has trails dedicated to dragonfly awareness.

Despite the ecological importance of bees and the attraction of dragonflies, the most popular insects throughout much of Western society are, without question, butterflies. Apart from being showcased in hundreds of butterfly pavilions, gardeners willingly invite them into their flower beds.

Huge numbers of butterfly enthusiasts travel the world in order to see and otherwise interact with these animals.



Rearing butterflies is a valuable industry, but needs to be carefully managed to minimize the spread of disease. Photograph copyright iStockphoto / LordRunar.

Taiwan attracts more than half a million visitors annually to enjoy the country's natural bounty of butterflies. The Sierra Madre Biosphere Reserve in Mexico, home to monarch butterfly overwintering aggregations, gets a quarter of a million visitors (as many visitors as are attracted by the charismatic koalas at the Lone Pine Koala Sanctuary in Brisbane, Australia). The threatened Karkloof blue (*Orachrysops ariadne*), found in KwaZulu-Natal, is featured prominently (complete with a Karkloof blue logo) in tourist itineraries for southern Africa.

Butterflies are also used for therapeutic purposes. In the butterfly gardens of Batticaloa, Sri Lanka, children affected by that country's civil war are provided with opportunities to interact with and learn about butterflies through play, music, and art activities. Similar therapeutic approaches involving butterfly gardens have been used for people living with Alzheimer's disease. Even dead butterflies are valued; framed displays of tropical species can be purchased in many home decor stores in North America. Studies indicate that worldwide retail sales of butterflies alone may be as high as $100 million annually, employing thousands of people in developed and developing nations alike. (It should be noted that commercial rearing and interstate shipping of butterflies for release at weddings and other events may result in the spread of diseases and is to be discouraged.)

Despite the large and growing interest, relatively few researchers have examined the human dimensions of human-insect interactions in a recreational setting. There are various reasons, though, why it is important to document them. First, such research provides quantifiable evidence that these interactions are not simply limited to a few eccentric individuals. Indeed, as my own efforts illustrate, this is a multi-million-dollar industry involving thousands of employees and millions of visitors, as well as tens of thousands of enthusiasts in their own gardens and neighborhoods. Second, such large, conspicuous, colorful, and mostly diurnal insects as bees, beetles, butterflies, and dragonflies are excellent candidates for conservation strategies, interpretive presentations, and public education (although the appeal of "creepie-crawlies" has also been successfully promoted in educational programs). Third, this type of research is valuable in helping to overcome the negative stereotypes often associated with insects—and also to convince managers and decision makers that not all human encounters with insects are bad, and that in fact many people actually seek them out.

Tourism is an important component of learning about insects and encouraging our interactions with them, but we should also recognize that engagement with insects and hands-on education begins in our own yards and neighborhoods. By integrating insects into recreational activities, we can foster among both young and old a recognition of their diversity and adaptability. Curiosity and openness toward these creatures can create a positive cycle of change, leading to greater respect for insects and increased appreciation for the invaluable services they perform.

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Butterfly gardening offers learning opportunities and a relaxing pastime, as well as the chance to create more habitat for insects. Photograph by Matthew Shepherd.

An Obsession with Odonata

Celeste Mazzacano

It's a warm sunny day in July, and I am crouching in a wetland off Oregon's Willamette River. I feel a certain companionship with the Pacific chorus frogs hopping nearby as the mud seeps around my knees and I crawl closer to the dragonfly, an irritatingly coy striped meadowhawk (*Sympetrum pallipes*). He flicks his wings impatiently, and the shutter on my camera clicks a bare second before he launches into flight. I pull myself free of the ooze and shake a spider from my hair, feeling well-compensated for my dogged stalking by the image on my camera screen.

For aficionados of Odonata (dragonflies and damselflies), few outdoor ventures are undertaken without a camera, a net, and several field guides. Dragonfly enthusiasts rival birders in the strength of their obsession—but what is it about these insects that captures the hearts and minds of so many?

Dragonflies and damselflies are among the most frequently encountered and easily recognized insects. Different species inhabit almost every kind of freshwater habitat; you can find them in ponds, streams, lakes, rivers, marshes, bogs, seeps, and even roadside

Odonates have a loyal following of enthusiastic "ode-ers," who are attracted by both their beauty and their acrobatic flying ability. Red rock skimmer (*Paltothemis lineatipes*), photographed by Dustin Huntington.

Young dragonflies live in water. They are aggressive predators, catching tadpoles and small fish as well as other insects. Nymph of a common green darner (*Anax junius*), photographed by John Abbott.

ditches. One species, the seaside dragonlet (*Erythrodiplax berenice*), breeds in saline waters such as salt marshes and tidal estuaries. Because they leave the water to mature, feed, and find shelter, you can also find odonates in meadows, open fields, and forests.

Their vibrant colors, large size, and incredible flying skills have captivated people throughout history. To some Native American tribes, dragonflies symbolized swiftness or pure water; to Japanese warriors, they were an emblem of strength. European and Euro-American cultures endowed them with darker symbology, calling them Devil's darning needles, eye-pokers, snake doctors, and horse stingers, and folk stories warned that children who told lies risked having their lips stitched together by a dragonfly as punishment. Their varied and evocative common names—shadowdragon, amberwing, sylph, boghaunter, spinyleg, sprite, firetail, jewelwing—echo the diversity and beauty of these insects.

The order Odonata—the name derives from the Greek *odontos*, for their toothed jaws—is divided into two suborders: large, sturdy dragonflies (Anisoptera), who perch with their strong wings held horizontally; and the more delicate damselflies (Zygoptera), whose wings are closed over their slender abdomens at rest. Adult odonates are noticeable for their acrobatic flight and bright hues, but their dull-colored, cryptic young are equally well adapted for their environment. Young dragonflies, called nymphs, larvae, or naiads, live in water. The bodies of some species are streamlined and minnow-like to help them swim through vegetation, while others are broad and flattened to burrow into mud. They obtain oxygen from water pulled into a gill chamber at the tip of the abdomen; this chamber doubles as a jet-propulsion unit, as the nymph can shoot water out of this cavity to escape from danger. Damselfly nymphs are elongated and slender; the oxygen they need is absorbed through their skin and through three delicate leaf-like appendages at the tip of the abdomen.

Both dragonfly and damselfly nymphs are aggressive predators. Fold-

A dragonfly's wings move independently of each other, giving these insects impressive aerial agility—even when they are badly damaged. Black saddlebags (*Tramea lacerata*), photographed by John Abbott.

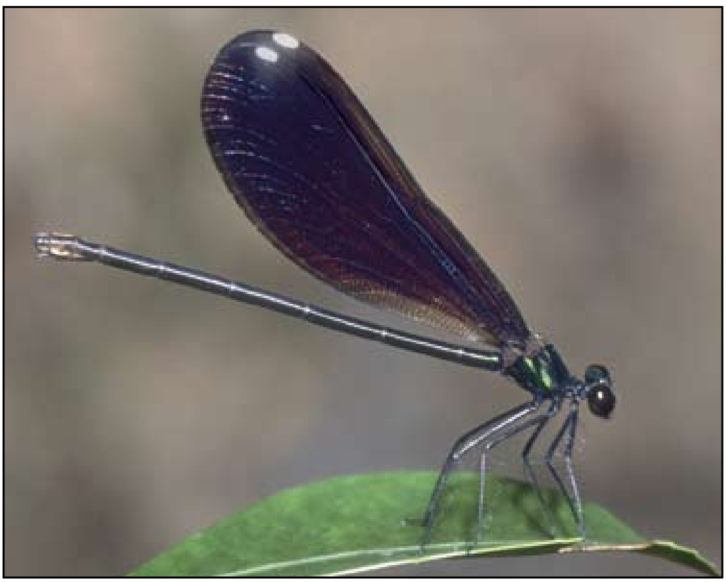
ed under the head is a hinged lower lip, or "labium," armed with teeth, which shoots out to snatch aquatic insects, tadpoles, and even small fish, bringing them back to the mandibles to be chewed and swallowed.

The majority of an odonate's life is spent underwater, as nymphs take from one to five years to develop, depending on the species. Like all insects, nymphs grow by molting through stages called "instars." In the final instars, the developing adult wing pads become visible. Nymphs stop feeding a few days before they emerge as adults. A nymph leaves the water for emergence, climbing up on a twig, plant, rock, tree trunk, or nearby dock or bridge. As emergence begins, the skin splits along the top of the thorax and the adult pulls its head, thorax, and legs free, followed by its abdomen. The newly emerged ("teneral") adult is soft, pale, and crumpled, and vulnerable to attack by predators. Soon the wings expand, the abdomen extends, the outer skin hardens, and the dragonfly takes to the air in a weak, fluttery maiden flight, leaving its cast-off skin ("exuvia") behind. These adults move away from the water to complete the process of maturing and to feed.

Adults lack the hinged labium of nymphs but are adapted to continue their predatory habits, with many specializations that render them ferocious aerial hunters. Their spiny legs are directed forward and held in a basket-like arrangement that enables them to scoop up prey in flight, capturing small insects such as flies, beetles, leafhoppers, and mosquitoes (thus the additional common name of "mosquitohawk"). They may forage by flying continuously and snatching prey in mid-flight (and often eating it on the wing), sallying forth from a perch to catch flying prey, or making slow searching flights through the vegetation to glean perched prey. Adults are eaten in turn by birds, robber flies, spiders, and each other—the fierce dragonhunter (*Hagenius brevistylus*), for example, is large enough to catch damselflies and even other dragonflies.

Among the odonates' most impressive features are their enormous compound eyes, composed of individual units called "ommatidia." No other insects have eyes as large; in some dragonflies, a single eye may have *twenty-eight thousand* ommatidia. These huge eyes provide a field of vision covering almost 360 degrees. If you could see with dragonfly eyes, you would see everywhere except immediately behind your head, and you'd be able to detect ultraviolet light as well as the full color spectrum. These amazing eyes make it possible for odonates to quickly detect movement and shape, allowing dragonflies to home in on prey and avoid being caught themselves—whether by a hungry bird or a net-wielding odonatist.

Odonates are also notable for their two pairs of large, transparent wings, criss-crossed by networks of veins that form complex patterns resembling living stained-glass windows. Their delicate appearance belies the strength of these wings and their underlying flight muscles, which make dragonflies some of the most dynamic fliers on the planet. Each wing works independently of the other three, enabling the insects to stop, hover, shoot upward, make sharp turns, and even reverse for short distances. Powerful flight muscles enable them to fly at speeds of up to thirty miles per hour—rivaling that of small



Damselflies are typically more delicate-looking than their larger dragonfly relatives. Ebony jewelwing (*Calopteryx maculata*), photographed by Bryan E. Reynolds.

songbirds—and to travel many miles in a day. In addition, their impressive flying ability allows some species to engage in annual migration flights across thousands of miles.

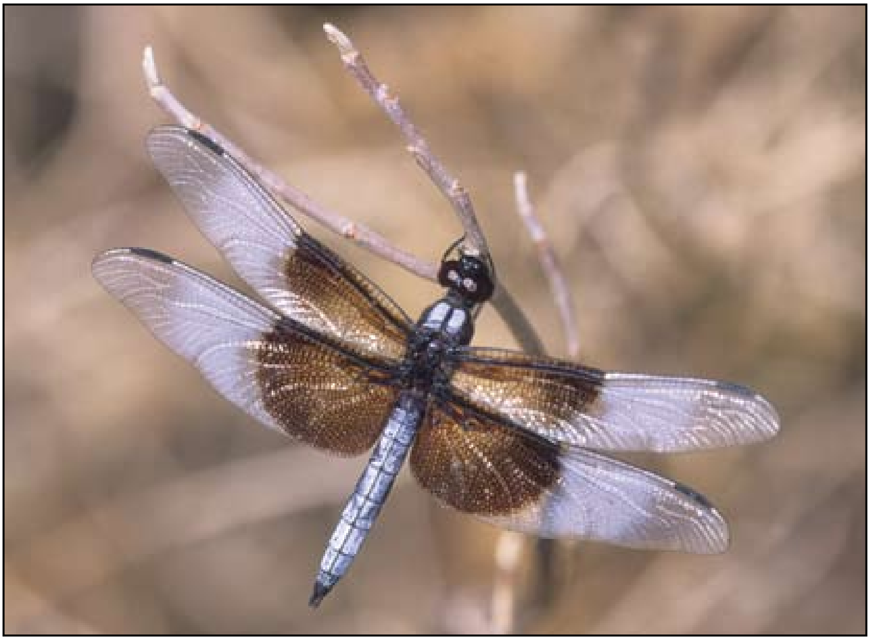
Mating occurs via an intricate mechanism unique to odonates, and may commence in flight. Males of many species claim territory in suitable egg-laying locations and patrol and defend it against rivals. Females tend to avoid water and the resident harassing males until they are ready to mate or lay eggs. Before mating, the male transfers a sperm packet from a pore near the tip of his abdomen to his secondary genitalia, on the underside of his second abdominal segment. He then uses forceps-like appendages on the tip of his abdomen to grab a passing female behind the head. If the female is receptive, she curves the tip of her abdomen up to the male's secondary genitalia, where it locks into place for sperm transfer; the male can also use his secondary genitalia to displace stored sperm from a female's previous mating.

The pair is now in a circular arrangement called the "wheel" position, though observers often point out that the shape made by the slender flexible abdomens of a damselfly pair more closely resembles a heart. In many species, the male continues holding the female behind the head after the wheel is broken and flies with her as she lays eggs, protecting his reproductive investment. If the male releases the female completely, he may fly along with and guard her, or she may oviposit alone.

Females distribute their eggs over a wide area to increase the likelihood of their survival. Depending on the species, eggs are laid in a variety of ways, including inserting them into vegetation or sediment, dropping them onto the water while hovering, or tapping the egg-laden abdomen on the water's surface. Some species lay eggs in dry seasonal wetlands that will flood later. Regardless of the technique employed, only a tiny proportion of the thousands of eggs one female can lay will survive to emerge as adults and take to the sky.

Odonates are long-term denizens of the planet; fossils of giant proto-dragonflies (Meganeuridae) with wingspans as great as twenty-six inches (sixty-eight centimeters) have been found in sediments three hundred million years old. Given their long history, diversity, and widespread distribution, it is tempting to assume that odonates can continue to fly successfully across a changing landscape. However, their absolute reliance on freshwater ecosystems means that odonates are losing habitat at an alarming pace. A large proportion of the world's wetlands have been drained, filled, or polluted, and introduced non-native fish can devour nymphs. The effects of global climate change are already being seen, with some species disappearing at the local level from seasonal ponds that have dried out repeatedly from the severe droughts that presently afflict many places.

There is still much for us to learn about dragonflies, and anyone interested in odonates and their conservation can make a real contribution. With digital photography, identification has become easier—a flighty or distant specimen can be zoomed in upon even if it never comes close enough to net, and a netted specimen can be photographed from different angles to provide clear views of specific characteristics. Pho-



Tennyson and other poets have extolled the exquisite beauty of dragonflies. Male widow skimmer (*Libellula luctuosa*), photographed by Bryan E. Reynolds.

tographs can be submitted to Odonata Central (www.odonatacentral.org), where they will be added to a growing species database.

Many professional and amateur odonatists maintain collections, and these collections have been critically important for scientific and educational endeavors in providing tissue for DNA and isotope analyses, identifying hybrids and subspecies, confirming range extensions, and delineating the variety of coloration and markings within a single species. Collecting and identifying exuviae is a good way to confirm that a particular species is reproducing at a site, and can provide important information about the ecology and life history of a species. A host of excellent guides facilitate identification, and listservs and Facebook groups provide a chorus of expertise and advice from a friendly community of fellow "ode-ers."

Just by taking note of the species you see in your daily activities, you can contribute significantly to our knowledge of dragonfly ecology, distribution, and status. So the next time you head out the door, grab your camera and a pair of binoculars, and keep your eyes open for these beautiful insects that Alfred Lord Tennyson described as covered in "clear plates of sapphire." But be warned, you just might become obsessed.

Celeste Mazzacano directs the Xerces Society's aquatic program and serves as project coordinator for the Migratory Dragonfly Partnership. Mazzacano is associate editor of Argia*, the news journal of the Dragonfly Society of the Americas.*

Neonicotinoids in Your Garden

Jennifer Hopwood and Matthew Shepherd

Gardens can be of great value for bees and other pollinators, providing nectar, pollen, caterpillar host plants, and bee nest sites. In recent years an increasing number of researchers and citizen scientists have surveyed bees in suburban and urban gardens across the United States and consistently they come back with records of dozens of species, even from community gardens in the Bronx and East Harlem in the heart of New York City. While usually they find common species, sometimes they've been surprised—the imperiled rusty-patched bumble bee (*Bombus affinis*), for instance, has been spotted by citizen scientists several times over the past three years in rural and suburban gardens in Illinois. Gardens can clearly support significant communities of bees, and, although they comprise only a small fraction of most landscapes, the benefits from these garden bees can spill over onto nearby farmland. Scientists in Britain have found that agricultural crops within half a mile of gardens are more likely to receive visits from bumble bees than are those further away.

Unfortunately, the value of gardens for sustaining pollinator populations can be drastically limited by the use of pesticides, insecticides in particular. While there are a number of ways to manage garden pests, commonly used garden pesticides can kill the "good" insects, even when applied according

Gardens can provide valuable habitat for a wide variety of insects. Metallic sweat bee (*Agapostemon*), photographed by Mace Vaughan.

The common buckeye (*Junonia coenia*) is one of a wide range of butterfly species that regularly frequent gardens. Photograph by Bryan E. Reynolds.

to the instructions on the label. Faced with well-stocked shelves of pesticides at stores and garden centers, many gardeners discover that deciding which one to pick can be tricky. For the health and wellbeing of pollinating insects, avoiding pesticides altogether may be the best option, but the fact is that many gardeners do employ pesticides.

Among the most widely used garden insecticides are the neonicotinoids, a group of seven chemicals that have recently been the subject of media scrutiny. Lauded by some as a breakthrough in pest control, neonicotinoids are denounced by others as the cause of a new “silent spring.”

These insecticides with the tongue-twisting name are a synthetic modification of nicotine, a highly toxic plant compound once commonly used as a pesticide. First introduced into the U. S. market in the mid-1990s, neonicotinoids were rapidly adopted for agricultural use as well as for ornamental plants growing in commercial nurseries, and they have become a ubiquitous presence on store shelves as the number of garden products containing them has expanded.

Neonicotinoids are systemic chemicals: taken up through various plant parts, they may then be distributed throughout plant tissues. This systemic action means that the chemicals can be applied to plants in a variety of ways—as a seed coating, as a soil drench around the base of a plant, by trunk injection, dissolved in irrigation water, as a spray to leaves. Whichever method is used, the pesticide is absorbed by the plant as it grows, making the plant tissues themselves toxic to sap-sucking insects such as aphids or plant bugs and to leaf-chewing caterpillars or beetles.

One oft-touted advantage of neonicotinoids over older pesticides is their lower toxicity to humans and other mammals (although unlike nonsystem-

Systemic insecticides are absorbed by a plant and spread through all its parts, including the nectar drunk by butterflies. American lady (*Vanessa virginiensis*), photographed by Bryan E. Reynolds.

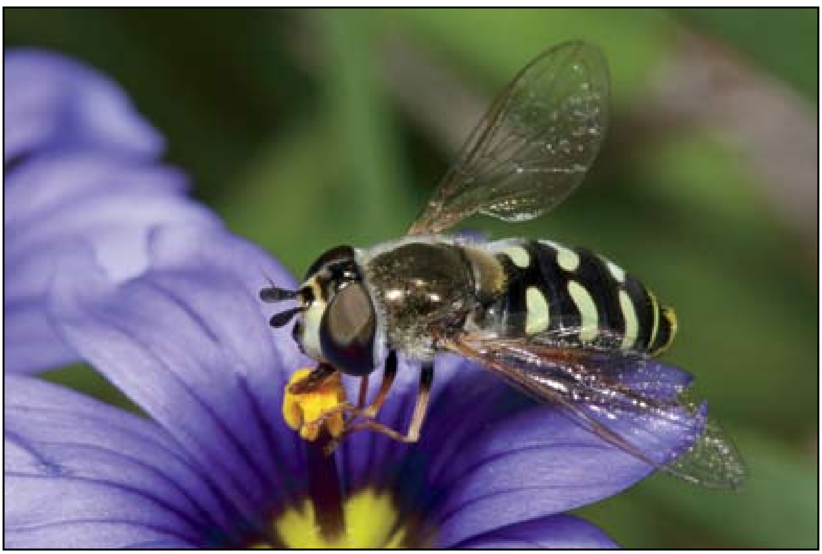
ic products, they cannot be washed off of the fruit you eat). Another advantage is that they may be applied in a very targeted manner, reducing potential exposure to many types of non-target insects that would contact a broadcast spray. In one example of such an application, growing corn plants absorb the insecticide from coated seeds rather than the field of corn being sprayed, thus eliminating a broadcast spray that could expose non-pest insects in the process (although, on the other hand, dust released from equipment during planting poses a risk to bees and other non-target insects). Unfortunately, although systemic applications may be claimed to be "safe" for non-target insect life, the toxins are present in pollen and nectar as well as in the rest of the plant, posing a threat to such flower-visiting insects as bees, wasps, butterflies, beetles, and flies.

Neonicotinoids are toxic to a number of beneficial insects, but the danger they pose to honey bees has drawn the most attention, given the recent large-scale losses of these domesticated pollinators. Some beekeepers and many in the environmental community consider neonicotinoids to be responsible for the phenomenon known as "colony collapse disorder." In recent years a variety of journalists, documentary film makers, and organizations have expressed this opinion, often in quite strong terms, despite the fact that numerous scientific studies implicate a range of factors, including several pathogens and a lack of floral diversity in the landscape. In order to better understand the scientific evidence, the Xerces Society recently undertook a review of the research, both that which has been published in high-profile journals and internal studies produced by insecticide industry scientists. *Are Neonicotinoids Killing Bees?*, a summary of our review, was released by Xerces this spring.

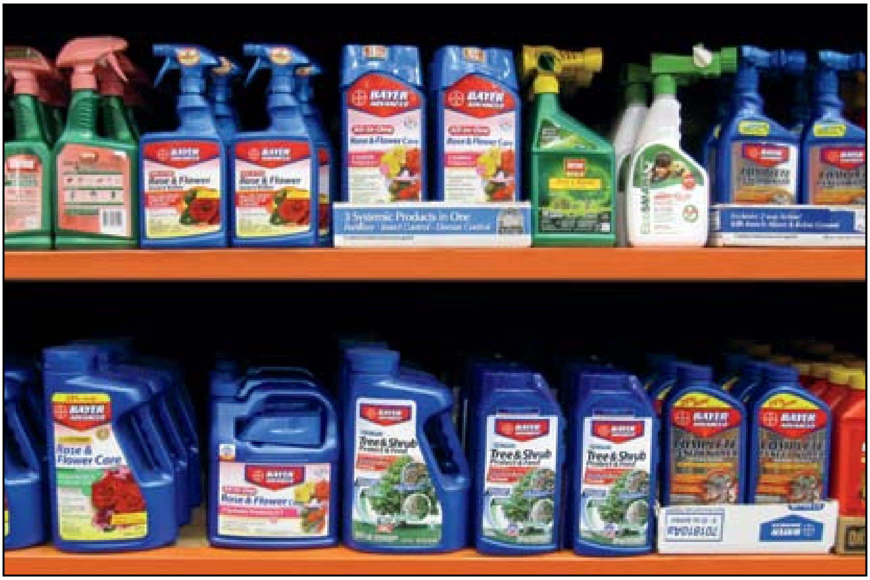
It is clear that neonicotinoids fed to bees in laboratory settings can kill them outright, but it is unclear how often neonicotinoids reach lethal levels in pollen and nectar in the field or garden. As one might expect, though, the amount of chemical that can be found in pollen and nectar is related to the amount applied to the plant, and, in products intended for agriculture, restrictions limit neonicotinoid application to quantities that typically result in sublethal levels being present in pollen and nectar. Still, although they don't kill, these smaller doses can affect the ability of bees to fly or navigate, impair their sense of taste, hamper their foraging activity, and reduce their ability to reproduce. These effects may impact individual solitary bees or combine to influence the overall health of bumble bee or honey bee colonies.

For example, recent research from France found that honey bees fed a sublethal dose had more difficulty finding their way back to their hive, and scientists in Britain found that bumble bee colonies fed very low doses of neonicotinoid-laced sugar water produced significantly fewer queens. While both of these studies were criticized for using doses higher than those that would be found in crops from treated seed, a growing body of research indicates that harmful but sublethal levels are routinely applied to crops that bees visit and that these might be negatively affecting bee populations.

Even more worrisome, and far more overlooked, are the levels of pesticides that are permitted in home gardens. Particularly notable are industry studies that have found extremely high levels of neonicotinoids in ornamental flowering shrubs and trees that are attractive to bees. Home garden products containing neonicotinoids can legally be applied in far greater concentrations in gardens than they can be on farms—sometimes at concentrations as much as 120 times as great—which increases the risk to pollinators. Pesticide companies themselves found that, when applied in the amounts suggested on the labels, some neonicotinoids could continue



As adults, flower flies feed on nectar or pollen; as larvae, they may eat aphids or other soft-bodied insects that are often considered garden pests. They can be exposed to neonicotinoids through all of these food sources. Flower fly (*Eupeodes*), photographed by Rollin Coville.



All but one of these garden insecticides contain neonicotinoids, and none of the labels indicate that they are poisonous to bees and adult butterflies. Photograph by Matthew Shepherd.

to be present in flowers at lethal levels eighteen months after application. But homeowners may not even be aware of the risk the use of these products poses. The labels of many of the products now on garden center shelves do not mention the toxicity of the products to bees, nor do they suggest ways to limit exposure to bees, such as by applying them only to non-flowering plants or after the plants have bloomed.

Efforts are underway to change the way neonicotinoids are labeled and regulated. Xerces is working with the U.S. Environmental Protection Agency and other organizations to develop new methods for testing the effects of insecticides on native bees—creatures that have been routinely ignored throughout the history of the pesticide regulation process—and to establish better assessment protocols. Still, it will take some years for any revisions to filter through the system and change the products that are for sale.

What you apply to your garden, though, is something that you have direct control over. To determine whether a pesticide contains a neonicotinoid, review the ingredients before you buy. Imidacloprid, dinotefuran, clothianidin, and thiamethoxam are all neonicotinoids found in home garden products. Much harder to control is the lingering presence of pesticides that have been applied to plants months before they reach your garden. There have been reports of dead bees—both honey bees and bumble bees—around commercially grown hanging baskets, and there is reason for concern about monarch caterpillars being affected by eating nursery-bought milkweed. Obviously, nurseries are applying pesticides to protect their investment; most people don't want to buy a ragged-looking plant, in the same way that they choose spotless fruit over blemished. When, however, this preference harms wildlife in gardens separated by distance and time from where the plant was grown, it is clear that we must find new ways to nurture plants grown for sale. Again, before you buy, take a moment to ask the garden center staff if they know whether the plants were treated with neonicotinoids.

Wildlife gardening is a well-established movement. It seems that every neighborhood has people encouraging wildlife into their yards. Choosing the best plants to attract butterflies, building bird houses and bee blocks, and creating ponds or log piles to provide shelter for frogs and myriad other small creatures are all effective ways to support a wide range of wildlife, and generations of gardeners have enjoyed beautiful gardens that are free of chemical threats. Systemic insecticides add an unfortunate additional layer of complexity for gardeners wanting to create a safe haven for insects and other wildlife, but with care the danger can be minimized or avoided.

Jennifer Hopwood is the Xerces Society's pollinator conservation specialist for the Midwest region. Matthew Shepherd worked in the Society's pollinator conservation program for several years and is now Xerces' communications director.

Are Neonicotinoids Killing Bees? A Review of Research into the Effects of Neonicotinoid Insecticides on Bees, with Recommendations for Action *is available from the Xerces Society. Visit www.xerces.org/neonicotinoids-and-bees/ to download a free PDF file or call 1-855-232-6639 to purchase a copy.*

Gardens are being created across the country to provide habitat for butterflies and bees. The Xerces Society offers information about creating such plots, as well as signs to raise awareness of the importance of pollinator habitat. Photograph by Celeste Ets-Hokin.

XERCES NEWS

Xerces Secures Its First Million-Dollar Grant

U. S. Agriculture Secretary Tom Vilsack announced in late August that the Xerces Society will receive a nearly $1 million Conservation Innovation Grant from the USDA Natural Resources Conservation Service to improve pollinator habitat on farms and ranches across the United States. The Society's partners in this project include Dr. Claire Kremen (University of California at Berkeley), Dr. Neal Williams (University of California at Davis), Dr. Marla Spivak (University of Minnesota), and Dr. Rachael Winfree (Rutgers University).

Working together across fourteen states, the group will investigate how to best manage wildflower meadows on the edges of farms, the use of organic techniques to control weeds in such pollinator meadows, and ways to quantify the effectiveness of various types of flowers in supporting crop-pollinating wild bees and honey bees. The partners will also collaborate with native plant nurseries to find ways to mass-produce seed for bee-friendly wildflowers that are not currently available in the nursery industry.

This work builds upon the success of earlier field tests by the project partners, researching the benefits of creating habitat next to cropland.

Pollinator habitat created at the USDA-NRCS Lockeford Plant Materials Center by Xerces and Lockeford staff. Photograph by Jessa Guisse.

Thank You to Whole Foods Market and Its Vendors

Concerned about the plight of bees, Whole Foods Market created Share the Buzz, a bee conservation initiative that it launched in the middle of June to tie in with National Pollinator Week. Displays in stores across North America featured Xerces' Bring Back the Pollinators campaign and encouraged their customers to take action to support bees.

Prior to the June initiative, the Society's pollinator conservation staff presented a nationwide webinar to Whole Foods' produce farmers and suppliers on the importance of protecting pollinators. Topics included an introduction to bee ecology, pollinator-friendly farming strategies, and ideas for restoring bee habitat on working farms.

During the two-week promotion, Whole Foods Market donated twenty-five cents to the Xerces Society for each organic cantaloupe sold. They sold well over a hundred thousand melons!

To cap the initiative, Whole Foods Market worked with its vendor companies—Annie's and the Hain Celestial Group, Inc., among others—to raise donations to support Xerces. Thank you to Whole Foods Market, its vendors, and all who made this effort such a success.

Bumble Bee Guidelines

Bumble bees, which are key pollinators of crops and wildflowers and essential for a healthy environment, are declining at an alarming rate. Biologists have found that several previously common species, such as the rusty-patched bumble bee (*Bombus affinis*), are now absent from much of their former territory.

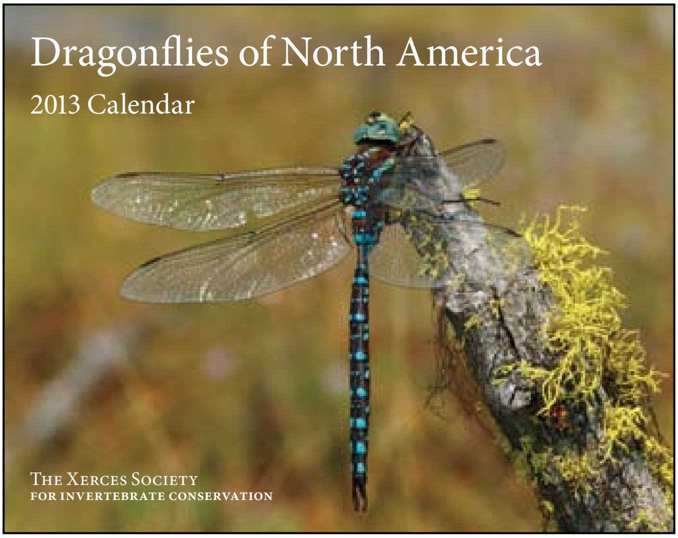
Surviving populations of these species need high-quality habitat to persist, as do all bumble bees. To assist landowners and managers in providing habitat, the Xerces Society this summer released *Conserving Bumble Bees: Guidelines for Creating and Managing Habitat for America's Declining Pollinators*. This booklet provides the essential information needed to create and restore appropriate habitat and describes ways in which land managers can alter current practices to be more in sync with the needs and life cycle of bumble bees. The guidelines also include regional bumble bee identification guides and lists of important bumble bee plants by region.

To buy a printed copy or to download a PDF at no cost, please go to www.xerces.org/bumblebees/guidelines/.

The Xerces Society's 2013 Calendar: *Dragonflies of North America*

Xerces has produced a calendar for the coming year featuring stunning photographs of dragonflies and damselflies, accompanied by brief notes about their natural history and behaviors. Month by month you will discover facts about these dramatic insects, learn how you can watch them in the wild, and find out how you can contribute to citizen-science projects tracking dragonflies as they migrate from Canada to Mexico.

All proceeds from calendar sales will directly support our conservation programs. Calendars are 9½ x 12 and



cost $15.00, including shipping. You can purchase them via our web site at www.xerces.org/calendar/ or by calling us at 1-855-232-6639.

Migratory Dragonfly Short Courses from Coast to Coast

In North America, huge numbers of migrating dragonflies can be seen flying south in the fall along both coasts and through the Midwest. This amazing phenomenon is widely witnessed, but poorly understood. The Migratory Dragonfly Partnership (MDP), the Xerces Society, and U. S. Forest Service International Programs recently collaborated to present a series of migratory dragonfly short courses across North America.

These full-day courses were intended for anyone interested in dragonflies and wanting to contribute to building our knowledge of dragonfly migration in North America. Each course covered dragonfly life history, ecology, and migratory behavior, and trained participants to identify key migratory species and contribute data to ongoing MDP citizen-science research projects.

Celeste Mazzacano, the director of Xerces' aquatic program and coordinator of the Migratory Dragonfly Partnership, presented courses in Oregon, Texas, and New Jersey. She was joined at some of these events by MDP partners Dennis Paulson, Mike May, and John Abbott. A fifth course, led by MDP partner Colin Jones, was presented in Ontario.

Protecting Butterflies of Pacific Northwest Prairies

The future of three Pacific Northwest butterflies—Taylor's checkerspot, the island marble, and the mardon skipper—relies upon the continuing presence of prairies, one of the region's most endangered habitats. The Xerces Society has submitted petitions to the U.S. Fish and Wildlife Service (FWS) asking for Endangered Species Act listing for all three butterflies.

Of the three, Taylor's checkerspot (*Euphydryas editha taylori*) may now be the most secure. Thanks to a petition from Xerces and our conservation partners, the FWS announced in early October that it was proposing that Taylor's checkerspot be declared "endangered," providing legal protection to the butterfly and more than six thousand acres of prairie in Oregon and Washington.

The mardon skipper (*Polites mardon*) has been less fortunate. Xerces petitioned the FWS in 2002; this September, a decade later, the FWS made a much-delayed announcement denying the skipper protection. This was bittersweet news. In recent years Xerces has worked extensively with the U.S. Forest Service, the Bureau of Land Management, and the Washington Department of Fish and Wildlife to study the butterfly and manage land for its conservation, which utimately contributed to the FWS decision not to list. Xerces commends the agencies and their staff for this work, which was recognized with a 2012 Wings Across America award. However, the skipper's future is still uncertain and much more work is needed to secure it at the many sites that are not being actively managed for the mardon skipper.

The island marble (*Euchloe ausonides insulanus*) is even more urgently in need of protection. Already extirpated from Canada, it is known to inhabit open grasslands on just two islands (San Juan and Lopez) in Washington state's Puget Sound. The island marble continues to lose habitat each year; it now occupies just eight of the fifty-two sites at which it was once found, and some of those have only a third as many butterflies as previously. In August Xerces filed a petition asking the U.S. Fish and Wildlife Service to extend Endangered Species Act protection to the island marble butterfly.

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For information about membership and our conservation programs for native pollinators, endangered species, and aquatic invertebrates, contact us:

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Life and death in the insect world: the larvae of many species of flower flies (family Syrphidae) are predators of aphids, which makes them valuable for controlling sap-sucking pests in the garden. Photograph by Alex Wild.

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Our cover photograph shows a beetle in the family Lampyridae. During daylight these insects appear unremarkable, but after dark they transform into flashing fireflies, creating summer-evening enchantment that lingers in our memories. Photograph copyright iStockphoto/ABDesign.