WINGS

ESSAYS ON INVERTEBRATE CONSERVATION

THE XERCES SOCIETY SPRING 2013

CONTENTS

Wings continues to evolve, as we introduce three new features: a conservation spotlight, invertebrate notes, and a staff profile. Fittingly, this issue is dedicated to change, with articles on metamorphosis, citizen scientists monitoring environmental events, and our efforts to protect a rare butterfly in a changing landscape.

Change

Scott Hoffman Black

Alter, adjust, convert, diversify, evolve, metamorphose, modify, revolutionize, switch, transform. All of these words are synonyms for "change," to which this issue of *Wings* is dedicated. Of course, change is all around us. Our seasons change with regularity, our kids change as they grow, and all of us change considerably as we get older. There are profound changes in store for our entire planet as the climate becomes warmer over the coming years.

Organizations experience change as well. In a little more than a decade, Xerces has grown from a handful of employees to a staff of twenty-five working across the United States. This growth has enabled us to establish offices in five states, which greatly expands our capacity to collaborate closely with conservation partners across the continent. Our larger staff has brought with it a broader range of knowledge and expertise, which in turn has allowed us to work more effectively to protect endangered species, provide habitat for pollinators, and conserve aquatic invertebrates.

With our growing staff, Xerces has been able to renew our commitment to the protection of monarch butterfly overwintering sites in California—including the annual Thanksgiving monarch count, a citizen-science project that monitors the numbers of butterflies at these sites—and to launch Project Milkweed, through which we encourage the planting of milkweed across the monarchs' breeding areas in both the eastern and western United States.

Over the last couple of years our citizen-science activities have expanded to embrace other, very different groups

No animals symbolize change as much as butterflies, with their dramatic transformation from crawling caterpillars to flying adults. Pipevine swallowtail (*Battus philenor*), photographed by Bryan E. Reynolds.

of insects: dragonflies and bumble bees. Xerces is a founding member of the Migratory Dragonfly Partnership, which is working with citizens in Mexico, the United States, and Canada to better understand dragonfly migration across North America. The MDP is collecting information through the Pond Watch and Migration Monitoring projects.

We have also started an initiative that gathers information about bumble bees, with a focus on imperiled species. This has already yielded great results in allowing us to better understand the conservation status of these bees. Over the course of the coming months, we will work with partners to expand this successful program significantly, broadening its focus to collect sightings of all of North America's bumble bee species.

In addition, the Society has dramatically increased the range of our pollinator conservation program. Over the last five years Xerces has presented more than a thousand Pollinator Conservation Short Courses, field days, farm conferences, workshops, and other events, reaching more than twenty thousand farmers and other agricultural professionals. Tens of thousands more people have been addressed through our publications—including *Attracting Native Pollinators*—and our web-based Pollinator Conservation Resources Center. Xerces' work with farmers and the USDA Natural Resources Conservation Service has led to more than 120,000 acres of habitat improvements for pollinators.

In keeping with the changing times, *Wings* is also undergoing a process of evolution. Our goal is to keep the best of the current *Wings*—the same small format, handsome imagery, and high-quality writing—while adding new content to help you be better informed and engaged. Each issue will contain a longer feature article and two shorter essays. The magazine will include more content directly relating to our work as an organization, a spotlight feature describing the work of one of our partners who are making a difference in invertebrate conservation, and a brief profile of one of our staff members. We hope you will enjoy the new shape of the magazine. We also hope that you will let us know what you think of the changes.

To kick off this transition we are honored that Piotr Naskrecki (author of several essays for *Wings* over the past few years) has penned the feature article, an evocative essay on metamorphosis accompanied by his stunning photographs. The other two articles focus on work undertaken by the Xerces Society. The first describes the expansion of our citizen-science projects for bumble bees and migratory dragonflies. The second details our decade-long effort to protect the Taylor's checkerspot butterfly.

Our inaugural "Conservation Spotlight" provides an overview of the work being done by the arboretum of the University of Wisconsin–Madison to protect and promote bumble bees, while our first "Staff Profile" introduces you to senior staff member Mace Vaughan, director of our pollinator conservation program. We are also introducing an "Invertebrate Notes" section, highlighting recently published books, new and interesting web sites, and noteworthy research from the last several months. The issue is rounded off with "Xerces News," our regular presentation of updates on the Society's programs and activities.

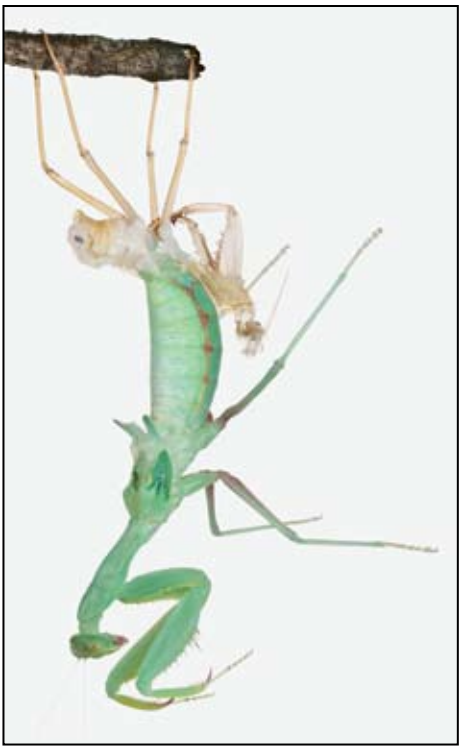
All of us here at Xerces hope you enjoy the new and improved *Wings*!

The Wonder of Metamorphosis

Piotr Naskrecki

It is almost one in the morning and here I am, still waiting with my eye glued to the viewfinder of the camera. In front of the lens the female nymph of a praying mantis hangs upside down from a branch, about to undergo a remarkable transformation. Soon she will leave her juvenile exoskeleton and emerge as a fully fledged adult, ready to embark on the final phase of her life. At last the mantis arches her back and an almost imperceptible fracture appears just behind her head, along the back of her long, neck-like pronotum. Her head emerges from the exoskeleton, followed slowly by her pronotum and the rest of her thorax, which now carries two pairs of small and shriveled wings.

Gentle, rhythmic, peristaltic movements of her musculature push her new, adult body, millimeter by millimeter, out of the old, dead, chitinous ghost of her former self. Her enormous prey-grasping, raptorial front legs and long antennae slide out first, followed by the second and third pairs of her spindly walking legs. Now all that holds her attached to the empty exoskeleton is the very tip of her abdomen. She pauses and will remain like this, hanging motionless, for about an hour. During this time the cuticle of her new exoskeleton will harden enough to allow her to move her legs and climb the branch she is hanging from to complete the expansion of her newly acquired wings. If she were to fall off now, with her new skeleton still soft and malleable (though already hardening fast), she would certainly end up disfigured, with her appendages twisted and unusable.



Hanging motionless from its old exoskeleton, a mantis may take an hour to harden before it can move. African praying mantis (*Sphodromantis lineola*), photographed by Piotr Naskrecki.

At last, in one quick upswing motion, the mantis grabs the branch above her head and breaks the last connection with her old exoskeleton. She now hangs from the branch by her front and middle legs, and those crumpled wings begin

A larva of the Dracula ant (genus *Amblyopone*) looks nothing like its adult sister. Photographed in Papua New Guinea by Piotr Naskrecki.

to expand rapidly. With air and hemolymph (blood) pumping into their tracheal frame, her wings appear to grow, turning into long, white veils that will eventually fold neatly onto her back. With this accomplished, the most dramatic event of this mantis's life is over. As she sits next to her empty nymphal "skin" (the "exuvia," in entomological parlance) it is hard to believe that this large, winged insect was once trapped inside. Looking closely at the structure of her body I can see not only her huge new wings, but also three small, lens-like structures on her head; these are the "ocelli," simple eyes that will help her orient herself while flying. On the underside of her body now sits her cyclopean ear, formed as a deep groove between her middle legs, which will allow her to detect ultrasonic calls of hunting bats; and her abdomen now carries fully developed reproductive organs. None of these structures were apparent on her body just a few hours ago.

I have been fascinated with insects my entire life, and have watched similar scenes unfold countless times, but I am yet to tire of this miraculous spectacle. There is nothing in human biology and behavior that compares to the process of arthropod molting and metamorphosis, nothing that will allow us to relate to the dramatic transition from one stage of development into another—and often remarkably different—stage. Our birth, as dramatic an event as it is, merely represents a moment of emergence as a fully formed individual following a period of steady gestation in the womb, with virtually all organs and senses already in place. Human development is boringly gradual, with no instantaneous morphological transformations to punctuate the passage from childhood to adolescence, from adolescence to puberty. We do not grow or lose an extra set of appendages overnight, and we cannot replace our skeleton if the old one becomes too small. We eat essentially the

same food as children that we do when we are adults, and we live in exactly the same environment.

None of this is of course a bad thing: there is safety in this uneventful constancy. As beautiful and fascinating as arthropod metamorphosis might be, it includes moments of profound vulnerability: weak and immobile, a molting praying mantis can be killed by a small cricket—its own future prey—and a hawk moth emerging from its pupal case can only try to crawl away from danger, unable to fly as it waits for its powerful wings to become functional. Every day, untold trillions of arthropods undergo metamorphosis—from caterpillar to chrysalis, from planidium to grub, from pupa into winged adult—and every day a large percentage of them die in the process. Why do it, then?

The answer to this deceptively simple question is twofold. The physical reason for molting—"ecdysis," a process that marks the transition from one stage of an arthropod's life cycle into another—is clearly dictated by the nature of its skeletal structures. Unlike a vertebrate's internal skeleton, which provides muscle attachments and does not constrain the growth of tissues surrounding it, an arthropod's chitinous exoskeleton has a limited ability to expand and must be shed periodically to

Immediately after emerging from the nymphal skin, adult insects pump fluids to expand their wings and other newly exposed body parts. Freshly emerged cicada clinging to a clay turret built by its nymphal stage in preparation for emergence, photographed in Suriname by Piotr Naskrecki.

accommodate growing tissue and newly appearing organs. The process of molting involves a complex sequence of cellular events, including "apoptosis," a process of programmed cell death that eliminates structures that will be unnecessary during the next developmental stage. Molting is regulated by a series of hormones, primarily the prothoracicotropic hormone, which initiates the molt; ecdysone, which controls the formation of new tissue; and juvenile hormone. In immature stages, juvenile hormone suppresses ecdysone's effect of triggering the development of adult structures, whereas the ultimate molt and metamorphosis into adulthood is controlled by yet another hormone, eclosion hormone.

Even more interesting is the reason for the often dramatic differences between the adult and larval stages of arthropods, and sometimes between larval stages of different ages. Entomologists classify insect developmental cycles into three broad categories: ametabolous, hemimetabolous, and holometabolous. The simplest one is ametabolous development, found in such primitively wingless ("apterygote") insects as firebrats and silverfish. In these lineages the young individuals differ from reproductive adults only in size, and molting continues indefinitely, even after the insects reach sexual maturity. (A similar pattern of development is found in other arthropods, such as crustaceans.) In hemimetabolous insects, immature forms may resemble adults in their general body structure, but lack wings and reproductive organs, and may lead a lifestyle different from that of adults; for example, dragonfly and damselfly nymphs are aquatic and use external gills for respiration. But most hemimetabolous insects have nymphs very similar to adults in their form and function—a young grasshopper looks like a grasshopper, even if it lacks wings and external hearing organs, and it usually feeds on the same things that its parents do. Not so in holometabolous insects such as beetles, butterflies, or wasps: their larvae are so drastically different from the adults that it is often nearly impossible to identify them as members of the same species. The typical sequence of holometabolous development includes an egg, a mobile larva whose only goal in life is to eat and eat some more, an immobile and nonfeeding pupa, and a reproductive adult ("imago").

A butterfly chrysalis is perhaps the most readily recognized symbol of insect metamorphosis. Chrysalis of a leafwing (genus *Anaea*), photographed in Suriname by Piotr Naskrecki.

In a process known as "hypermetamorphosis," some insects, often those parasitizing other species, have a highly

This series of images shows three of the four phases of holometabolous insect development: larva, pupa, and adult. The egg is not shown. Ground beetle (*Dicaelus dilatatus*), photographed by Piotr Naskrecki.

mobile larval stage known as the "planidium," which actively searches for its host before turning into a more typical feeding larva.

A cursory glance at the diversity and species richness of insects with hemimetabolous versus holometabolous development immediately reveals that those with the latter have been far more successful: beetles alone, with more than 350,000 described species, vastly outnumber all hemimetabolous insects, and the evolutionary success of wasps, moths, and flies is similarly staggering. It appears that by finely partitioning their life cycle into periods of feeding (larva), major body restructuring (pupa), and reproduction (adult), during which the immature stages do not compete directly for resources with the adults or each other, holometabolous insects have been able to dominate most of the world's terrestrial ecosystems. While a young praying mantis occupies the same niche and competes with its parents for the same food, an algae-filtering mosquito larva might as well live on a different planet as far as its nectar- and blood-feeding parents are concerned.

Entomologists sometimes refer to larvae of holometabolous insects as "digestive tracts on caterpillar treads," an apt description for organisms, such as caterpillars of the tobacco hornworm

moth, that are capable of increasing their body mass by 1,500 percent between two molts. But once the feeding time is over, a larva molts into a pupa and its no-longer-needed larval structures, such as the prolegs along the body of a caterpillar or the enormous abdomen of a beetle grub, either are eliminated through apoptosis or undergo remodeling in order to serve new functions. New structures, such as wings or large compound eyes, along with their corresponding neural networks, are developed from clusters of cells known as "imaginal disks," which have remained inactive until this point, and all these extraordinary changes take place inside a dormant, seemingly lifeless pupa. Once the remodeling is completed, a flying sex machine emerges. From this point on feeding is a secondary function, needed only insofar as it increases the chance of successfully mating or laying eggs. In fact, many insects such as cecropia moths eschew food entirely as adults, relying on the reserves left from their larval period.

Arthropods, with their rigid external skeletons that force them to molt periodically, are not the only animals that undergo metamorphosis in the course of their development. Freshwater clams and oysters start their lives as tiny, soft-bodied larvae—some of which are parasitic on gills of fish for a brief period—before gradually turning into sessile adults, safely ensconced in calcareous shells. Some marine snails start as pelagic larvae, propelled with wing-like lobes of their translucent bodies. Even some vertebrates—amphibians are the best-known example—undergo metamorphic changes during their development. But nothing in the animal kingdom rivals the drama of the rapid transition from an apparently lifeless pupa into a high-flying adult insect.

Humans have always been fascinated with insect metamorphosis, although it took a surprisingly long time to unravel the mystery of how a caterpillar turns into a butterfly. It was not until 1699, when the Dutch naturalist Maria Sibylla Merian sailed to the shores of Suriname, that anyone documented in detail the process of insect metamorphosis. Her exquisite illustrations were the first scientifically accurate depictions of life cycles of caterpillars and moths. Merian's work pointed the way toward modern understanding of metamorphosis, with all the intricacies of hormonal regulation of gene expression and the significance of competition between species living within the same niche.

We are able to use this knowledge to better understand our own development, to elucidate the evolutionary history of arthropods, or to develop more effective insecticides. But, although we now fully understand the mechanism of insect metamorphosis, for many of us the sense of wonder at this most amazing natural spectacle endures. And this is why I am still looking through my camera at a molting mantis at four in the morning.

Dr. Piotr Naskrecki is an entomologist, photographer, and author, based at the Museum of Comparative Zoology, Harvard University. His research focuses on the evolution of katydids and related insects, and the theory and practice of nature conservation. As a photographer, Piotr strives to promote appreciation and conservation of invertebrate animals.

The Pendulum Swings: Citizen Science and Conservation

Rich Hatfield

Some of our most significant scientific discoveries were spearheaded by scientific amateurs. The use of the word "amateur" can evoke thoughts of inexperience, but amateur scientists were often experts in their fields and provided seminal observations: prime examples include Benjamin Franklin, Charles Darwin, Thomas Edison, Gregor Mendel, and John Ray. Their discoveries, arising not out of professional obligation but stemming instead from curiosity or an affinity for a particular topic (after all, amateur means "one who loves"), advanced knowledge and changed our understanding of the natural world.

Over the last century, science has become an increasingly professional pursuit, seemingly appropriate only for those who have undertaken formal training. This transformation has contributed to improved standards for scientific practice and the development of the peer-review process; it has also provided access to expensive technical equipment. There are drawbacks, however: the professional scientist typically has publishing and teaching obligations, and research questions are often limited in scope by funding sources, geography, and available personnel.

If the twentieth century saw an in-

Training workshops, such as this one in the monarch grove of the Ardenwood Historic Farm, prepare citizen scientists to continue a tradition of skilled amateur natural historians that stretches back for centuries. Photograph by Carly Voight.

crease in the professionalization of science, the pendulum may now be swinging in the other direction. The tradition of amateur natural historians continues into the twenty-first century, with self-motivated individuals providing critical expertise for many less-studied taxa. To stretch budgets and expand their reach, organizations and professional scientists are tapping into this wealth of knowledge and turning once again to amateur scientists to collect data.

Citizen-science projects are not new, nor have their contributions to science been small. The Audubon Society has just conducted its 113th Christmas Bird Count, and the National Weather Service Cooperative Observer Program is celebrating its 123rd year. The Fourth of July Butterfly Count, started in 1975 by the Xerces Society and now run by the North American Butterfly Association, is nearing its fortieth year. These long-term datasets have made essential contributions to our understanding of climate, ecology, and wildlife conservation.

Since the late 1990s, the number of citizen-science efforts has skyrocketed. There are projects for which local enthusiasts are recruited to submit their observations of birds (Project FeederWatch, Backyard Bird Count, ebird), insects (Great Sunflower Project, Lost Ladybug Project, Beespotter, Monarch Watch), plants (National Phenology Network, Project BudBurst), mammals (Bat Detective, Project Squirrel), and fungi (Mushroom Observer). There are also web sites to help establish research projects, recruit volunteers, and document biodiversity (Project Noah, iNaturalist).

Not only are citizen-science projects swelling in popularity, they are increasingly influential in the scientific community. A quick keyword search for "citizen science" in the Web of Science, a scientific-journal database, shows just a handful of articles in this realm published before 1996. Since then the number of articles per year has grown rapidly; nearly a hundred were published in 2012. Data from citizen-science projects are being used to find rare organisms, track migration patterns, detect

Digital photography and the internet can connect citizen scientists with national experts. Photograph by Susan Carpenter, courtesy of the University of Wisconsin–Madison Arboretum.

Citizen-science projects allow close-up encounters with wildlife that otherwise might only be glimpsed as it flashes by. Photograph by Alexa Carleton.

species declines, create climate-change models, and discover the complex geometry of biochemical molecules.

Another factor driving the increase in citizen science is the transformation to an increasingly digital society. Nearly half of the U.S. population has a smartphone capable of collecting data nearly anywhere in the country. With such widespread computing power, citizen scientists can quickly submit valid, georeferenced data. Furthermore, citizen scientists can easily share their findings, including photographs, through social networking, and add to their knowledge via accessible web content and project collaborators. Data collection is thus fun, informative, and easy.

The Xerces Society is currently engaged in three major programs that directly benefit from the participation of hundreds of engaged citizens: the Migratory Dragonfly Partnership, Project Bumble Bee, and the Western Monarch Thanksgiving Count. Engaging citizens in its work is nothing new for the Society. In addition to having originated the Fourth of July Butterfly Count, over the last two decades Xerces has played a leading role in local community monitoring of creek health using aquatic invertebrates and, more recently, in surveying freshwater mussels in the Pacific Northwest.

The Migratory Dragonfly Partnership, a collaboration among dragonfly experts, non-governmental organizations, and federal agencies, is working

Rusty patched bumble bee (*Bombus affinis*), photographed by Christy M. Stewart, a participant in Xerces' Project Bumble Bee.

to understand dragonfly migration in North America and to promote conservation of the wetland habitats on which dragonflies rely. The group is developing an international network of citizen scientists to investigate dragonfly migration via three avenues: Pond Watch, Migration Monitoring, and the Stable Isotope Project. In 2012, more than two hundred people submitted 725 reports, and six hundred specimens were collected for stable-isotope analysis. The knowledge gained expands our understanding of dragonfly migration routes and timing in North America. These contributions also will be useful in focusing future conservation efforts.

The second citizen-science project managed by Xerces focuses on bumble bees, in particular tracking the status of four rare species across North America. Under the umbrella of Project Bumble Bee, more than twelve hundred citizen scientists have participated since 2009, generating eighty-six verified records of the four species of interest. Additionally, we launched a project in 2012 to collect information about nest locations; data from more than a hundred nesting sites of eleven different species of bumble bees have already been submitted. Xerces is using this information to identify the current distribution of imperiled species, to reach out to state and federal agencies, and to educate the public about the importance of protecting bumble bee populations. This project is now expanding. In collaboration with Wildlife Preservation Canada, the University of Ottawa, and the Montreal Insectarium, the Bumble Bee Watch web site is being developed through which people will be able to identify all North American bumble bees, and to submit sightings of any bumble bee or nest.

The Western Monarch Thanksgiving Count, in which a dedicated team of volunteers has been conducting annual surveys of overwintering monarchs at sites in coastal California since 1997, engages around a hundred participants each year. At some sites, this work has re-

vealed a greater than 80 percent decline of monarchs over the past fifteen years, a striking finding that has spurred wider interest in the conservation of western monarchs. Data from the Thanksgiving count have been used by citizens seeking to protect monarch overwintering habitat from housing developments, and by scientists wanting to better understand changes in the monarch population and the contributing factors.

Citizen-science projects have the capacity to increase scientific literacy, build social capital in our communities, and enable new discoveries. Involvement in such projects provides an opportunity for almost anyone—from expert taxonomist to enthusiastic volunteer—to engage in educational and social activities that will help to gather the evidence that we need to document and preserve biodiversity.

As more people participate in citizen science, we are maintaining the tradition within which many of our fundamental scientific discoveries were made. By changing bystanders into participants and engaging people directly, we have the opportunity to re-establish a more universal reverence for the natural world and to become better stewards of our planet.

Rich Hatfield is a conservation biologist with Xerces' endangered species program.

Find more information about Xerces' citizen-science projects at www.xerces.org.

Data collected by volunteer monitors for more than a decade has produced a detailed picture of the status of monarchs overwintering along California's coast. Photograph by Carly Voight.

Saving a Rare Butterfly, Step by Step

Scott Hoffman Black

On October 11, 2012, the U.S. Fish and Wildlife Service proposed that the Taylor's checkerspot butterfly be listed as endangered under the Endangered Species Act. Such protection is vital to the recovery of this beautiful butterfly, and, while it is something to celebrate, this success is just the latest installment in a sustained effort that stretches back more than a decade.

One of my earliest—and most memorable—encounters with Taylor's checkerspot was on a warm spring day in 2003. With Mace Vaughan (then a conservation associate for Xerces and now the director of our pollinator program), I had made the ninety-minute drive from Portland south to Corvallis through Oregon's Willamette Valley. We met Dana Ross, a local lepidopterist, at a trailhead and hiked up to a small meadow. As we crested the hill, we were met with one of the most extraordinary sights I have ever seen: filling the air were hundreds of brightly colored butterflies, each marked with a checkerboard pattern in orange, white, and black. Some males were defending their territories and working to find mates. Other butterflies were nectaring on wild strawberries,

The aptly named checkerspot butterflies are distinguished by the orange, white, and black patterns on their wings. Taylor's checkerspot (*Euphydryas editha taylori*) nectaring on wild strawberry, photographed by Rod Gilbert.

The correct host plants for females to lay eggs on and for caterpillars to eat are essential components of butterfly habitat. Invasive species can crowd out the host plants. Photograph by Rod Gilbert.

and many were simply sitting and basking in the morning sunshine. All of this was taking place in an area of less than an acre.

Making this occasion all the more special was the knowledge that we were in the presence of the only known population of this butterfly in Oregon. Taylor's checkerspot (*Euphydryas editha taylori*) is a prairie species that was once found on grasslands throughout the Willamette Valley, in areas to the north and south of Washington's Puget Sound, and on southern Vancouver Island in British Columbia. Its historic range and abundance are not precisely known, but over time the butterfly had been documented at more than seventy locations. By the turn of the twenty-first century, the number of known sites had fallen to barely more than a dozen, with none in British Columbia and just one in Oregon.

Shortly before our 2003 trip, the Xerces Society had submitted a petition to the U.S. Fish and Wildlife Service (FWS) to request that Taylor's checkerspot be protected under the U.S. Endangered Species Act. The dramatic decline in known sites and the lack of information about this butterfly led Xerces to conduct a survey for Taylor's checkerspot populations in Oregon. The goals were three-fold: to determine the size of the known population, to resurvey historic sites, and to search for additional populations in areas that had the proper habitat characteristics.

We knew that several of Oregon's historic sites had likely been lost to development and agriculture—grasslands are far less common in the Willamette Valley than they once were—and encroachment by invasive weeds; now, by poring over maps and aerial photographs, we were able to identify additional sites that seemed to have the right conditions to support the butterfly. We divided up the task: Mace and I would visit the historic sites, and Dana would track down and evaluate the potential new locations.

Our survey of the historic sites confirmed that Taylor's checkerspot was

missing from every one of them. Some sites were themselves completely gone—a house had been built on one of them, for instance—and others were choked with Scotch broom, an invasive European shrub, squeezing out the butterfly's required host plants, which include harsh Indian paintbrush and a nonnative plant, narrow-leaf plantain.

Fortunately, Dana had more positive results: he discovered a hitherto unknown population. And this new population turned out to be one of the largest known at the time, occupying a cluster of more than five interconnected sites. Further good news was that these butterflies were on land owned by Benton County and managed by the county's Natural Areas and Parks Department.

We continued our search in 2004, surveying two dozen additional sites in collaboration with Mikki Collins of the FWS's Oregon office and Nan Vance of the Bureau of Land Management. Although no new populations were found, we established that both of the known populations occupied bigger clusters of sites than previously thought.

There is a popular misconception that landowners are uniformly recalcitrant when it comes to aiding in the conservation of endangered species on their holdings. On the contrary, a number of landowners were hoping that we would find this butterfly on their property. At one stop, Dana, Mace, and I eagerly emerged from the car, keen to see land that had been restored as native prairie. The landowner was happy to see us, later telling a reporter, "These three guys jumped out of the car, all wearing dark sunglasses. They seemed like they might be with the butterfly FBI."

Finding the butterfly is just one step toward its conservation. Xerces worked to broker a deal with the landowners who had the larger population in their care. In concert with Benton County Parks and one of the county commissioners we developed an agreement that enabled the county to manage the private land for the benefit of the butterfly. We then collaborated with the county parks department on a plan to control invasive weeds at the site and to limit access to the meadow.

Because this checkerspot population also occupies part of a power transmission right-of-way, we joined forces with Mikki Collins and staff of the Bonneville Power Administration (which manages the transmission line) to formulate a plan laying out steps that the BPA can take to help the butterflies.

Benton County and the FWS worked together to prepare a countywide Habitat Conservation Plan that provides for continuing protection for prairie species—including Taylor's checkerspot—on sites under county jurisdiction.

The effort to protect a butterfly, of course, needs to extend over its range regardless of political boundaries. In Washington state there have been several initiatives to protect places harboring the checkerspot. The Department of Fish and Wildlife, together with other state agencies and nonprofits, has surveyed the butterfly populations and worked to gain a better understanding of how to restore their habitat. Department of Defense land managers and biologists have collaborated with a range of organizations, including the Nature Conservancy and the Center for Natural Lands Management, to improve habitat on military training areas at Joint Base Lewis-McChord. Xerces also worked

The wildflower-rich grasslands that many butterfly species rely upon are disappearing from modern landscapes. In Oregon's Willamette Valley, grasslands have been lost to agriculture, urban development, and invasive plants. Less than 1 percent of the Valley's historical area of prairies now remains. Photograph by Mace Vaughan.

Taylor's checkerspot spends much of the year (from late summer to the following spring) as a chrysalis. Photograph by Rod Gilbert.

with the Washington Department of Fish and Wildlife and others to convene researchers and conservationists with the goal of sharing knowledge of Taylor's checkerspot and compiling all of the known information in one place. From there we developed plans to detail next steps to conserve this butterfly.

Even with all of this work, the Taylor's checkerspot is still highly imperiled. It was included in a settlement agreement stemming from legal action by the Center for Biological Diversity and Wild Earth Guardians to compel listing under the Endangered Species Act of those that the FWS has deemed "candidate species" for protection, many of them having languished for years in apparent limbo. As a result, the FWS has proposed the butterfly for protection. Following through with this listing is clearly urgent, given that most of the checkerspot's former habitat has disappeared and what remains is under threat. Endangered species listing will provide more funding for research, habitat restoration and acquisition, site protection, and, potentially, reintroductions into historic sites.

The Xerces Society's efforts on behalf of Taylor's checkerspot started out as a plea to the government to take action for its protection. After a decade of work—searching for new populations, developing agreements to protect important habitat, designing management plans for specific sites, and garnering media attention—it is, at last, likely that the butterfly will receive the benefit of federal protection.

But listing cannot be the end of the story. Much more needs to be done before this species will ultimately recover. With willing landowners, dedicated lepidopterists, responsive state and federal agencies, and determined nonprofit organizations working together, many more people will someday have the opportunity to witness the spectacular flight of Taylor's checkerspot.

Scott Hoffman Black is executive director of the Xerces Society.

The University of Wisconsin–Madison Arboretum

Located in the middle of the Midwestern city of Madison, the University of Wisconsin–Madison Arboretum attracts about a million people annually. Scientists, land managers, students, gardeners, community members, and visitors from all over the world use the Arboretum for research, workshops, classes, tours, and field trips, as well as simply for enjoyment of its nearly twenty miles of trails. The land on which the Arboretum resides was once agricultural fields and pastures, but, thanks to extensive restoration efforts, it has been transformed into a diverse mix of environments representing Wisconsin's native plant communities. The Arboretum's twelve hundred acres are home to savannas, prairies, deciduous and coniferous forests, and wetlands, in addition to horticultural gardens featuring both native and ornamental plants.

This assortment of habitats benefits many types of wildlife, but the Arboretum has become known as a refuge for bumble bees in particular. Eleven species have been recorded there—including the highly imperiled rusty patched bumble bee (*Bombus affinis*)—a particularly impressive list given the relatively small parcel of land and the fact that it is situated within an urban area. The Arboretum's remnant and restored habitats provide bumble bees with season-long foraging resources from the early-spring flowering of willows in wetlands to the early-autumn blooming of goldenrods in prairies. In addition, the heterogeneous landscape provides a wide variety of nesting opportunities, from old stone walls to grass tussocks, from decomposing logs to rodent holes.

Although the diversity of bumble bees at the Arboretum can be attributed in part to the diversity of habitats found there, it can also be seen as a product of the range of land management practices adopted by the Arboretum's staff.

Bumble bees have two basic needs: a place to nest, and flowers on which to forage. To provide the former, the Arboretum retains snags for as long as is safe, and leaves in place fallen logs, leaf litter, brush, and bunch grasses. Visitors may sometimes feel that such detritus is untidy or an eyesore, but these features provide valuable opportunities for nesting and overwintering.

The staff is also active in improving flowering habitats, with the aim of ensuring blooming plants throughout the bumble bee flight season (which in this region is March to September). Habitats are enhanced with native species known to be attractive to bumble bees, and prairies and other areas are carefully managed to maintain open, weed-free conditions. The Arboretum's prairies are burned a parcel at a time, which leaves refuges for bees; invasive plants are removed by hand weeding or targeted herbicide applications; and insecticides are rarely used and carefully targeted at protecting the trees in the horticultural collections. Monitoring to determine which plants bees are using helps to in-

form the Arboretum's activities.

Complementing its land management, the Arboretum has an active education and outreach program to gardeners, students, community members, and staff. In a variety of ways it advocates for bumble bees and encourages bee-friendly practices within its confines and beyond. It has initiated a multi-year citizen-science monitoring project to document and photograph bumble bee species that forage and nest in its many habitats. Presentations, tours of the native-plant garden, and volunteer gardening sessions, as well as family activities such as bee-spotting walks, provide chances for the public to learn about bees and to participate in caring for the grounds. The Arboretum also hosts events for land-management professionals, such as a 2010 Xerces Society Pollinator Conservation Short Course for land managers and agency staff, and, in 2012, a workshop on native-pollinator conservation for Arboretum employees, volunteers, and partners.

The Arboretum recognizes how important its land is for bumble bees, and also, in turn, how important bumble bees are for maintaining healthy plants and sustainable ecosystems. It provides a refuge for both common and imperiled species, and its efforts highlight the significance of bumble bees in the landscape in such a way as to generate public support for the care of bumble bee populations. Through its management and its programs, the Arboretum has established itself as a regional center for bumble bee conservation.

This bucolic landscape is bounded by freeways and housing, yet thoughtful management has created the right conditions to support nearly a dozen species of bumble bees, including the nationally rare rusty patched bumble bee (*Bombus affinis*). Photograph by Molly Fifield-Murray, courtesy of the University of Wisconsin–Madison Arboretum.

INVERTEBRATE NOTES

New Books

People have watched and enjoyed butterflies for centuries, and there are many excellent field guides to aid in identifying these beautiful insects as flying adults. Identifying caterpillars has been harder. A pair of new books offers readers both identification assistance and natural history information.

Owlet Caterpillars of Eastern North America (David Wagner, Dale Scheitzer, Bolling Sullivan, and Richard Reardon; Princeton University Press), may focus on just one family of moths, but owlets are the largest family of butterflies and moths, Noctuidae. There are 2,900 species of owlets in North America alone—four times as many as all the butterflies—and this well-written and generously illustrated book will enable you to identify hundreds of those from the eastern half of the continent. Each species profile has details of how to recognize the caterpillars, where to find them, and their preferred host plants.

The second book covers a smaller area on the opposite side of the continent, the Cascadia region, which the authors define as Washington state and adjoining areas. What makes *Life Histories of Cascadia Butterflies* (David James and David Nunnallee; Oregon State University Press) stand out are its illustrations of every stage of a butterfly's development: egg, each larval instar, chrysalis, and adult—and for all 153 species of butterflies in the region, plus an additional five subspecies. This is a remarkable achievement, made all the greater by the detailed life history descriptions that accompany the photographs.

Web Sites of Interest

Continuing with the theme of butterflies and moths, there are a growing number of online resources that provide a wealth of information and identification help. The three listed here are particularly useful, offering good photographs, accurate life-history information, and reliable distribution maps.

Butterflies and Moths of North America (BAMONA):
www.butterfliesandmoths.org.

Butterflies of America:
www.butterfliesofamerica.com.

Pacific Northwest Moths:
pnwmoths.biol.wwu.edu.

Recent Research

Dragonflies make tadpoles grow larger tails. A study by University of Michigan scientists showed that tadpoles grow bigger tails when stressed by the presence of dragonfly nymphs. Wood frog (*Rana sylvatica*) tadpoles were placed in water shared with dragonfly nymphs that were caged so they could not eat

the tadpoles. The immediate response of the tadpoles was to remain motionless to avoid detection. After several hours they began moving again, and over the next week their tails grew larger; stronger tails would help them escape the jaws of dragonflies. These changes were controlled by corticosterone, a stress hormone. (Maher, J. M., E. E. Werner, and R. J. Denver. 2013. Stress hormones mediate predator-induced phenotypic plasticity in amphibian tadpoles. *Proceedings of the Royal Society B.* 280: 20123075 doi:10.1098/rspb.2012.3075.)

Beetles navigate by the stars. For dung beetles, the ability to roll a dung ball quickly away from the dung pile and competing beetles is important—and they are remarkably good at rolling in a straight line. Researchers in South Africa showed that nocturnal beetles use the stars to navigate via photoreceptors that sense polarized light. When scientists blocked the beetles' sky view by fitting them with tiny hats, they lost their sense of direction and rolled their dung balls haphazardly. (Dacke, M., E. Baird, M. Byrne, C. H. Scholtz, and E. J. Warrant. 2013. Dung beetles use the Milky Way for orientation. *Current Biology* 23:298–300.)

Native bees are better pollinators. An international team of researchers, including several of Xerces' scientific advisors and project collaborators, has concluded that native pollinators can help farms produce bigger harvests. The study looked at pollinator visitation in hundreds of farm fields on six continents and in forty-one crop systems, and demonstrated that yields increased with the presence of more native bees and that wild pollinators are more efficient than honey bees. The authors recommend integrated management policies, including restoring and creating habitat on farms and consideration of pollinators during pesticide applications. (Garibaldi, L. A., I. Steffan-Dewenter, R. Winfree, et al. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science* 339:1608–1611.)

Dung beetles were fitted with hats to block their view of the sky. This hat is clear, a control in the experiment. Photograph by Marie Dacke.

STAFF PROFILE

Mace Vaughan, Pollinator Conservation Program Director

What got you interested in insects? I have always been fascinated by nature, but never really paid any attention to insects until after college. Then I began keeping honey bees, which led me to discover the amazing diversity of insects visiting flowers. After that, I was hooked.

How did you first hear of the Xerces Society? In the late 1990s, I was working as an intern with the nonprofit Canyonlands Field Institute in Moab, Utah. As a class project, we were asked to design our own nonprofit organization; I outlined one that took on the challenges of invertebrate conservation. When I shared this idea with my mentor, Tim Graham (then a USGS biologist), he burst my bubble, letting me know that the Xerces Society had been at it since the early '70s. Within a couple of weeks, I had become a Xerces member—and I was determined to work there in the future.

What's the best thing about your job? The people! The staff at Xerces are terrific. And, I work with farmers, biologists, and conservationists across the country who are passionate about bees, about biodiversity, about conservation.

Who's in your family? Besides my wonderful wife—who also works full time in conservation—and my bright and beautiful daughter, we have a dog, a guinea pig, a snake, a spider, and a fish.

What do you do for relaxation? Playing the guitar, rock-climbing, hiking, biking, and camping.

Who is (or was) your environmental hero? I have two heroes. The first is unsurprising: Aldo Leopold really pulled the pieces together for me. And, he undertook his work in a managed landscape, where he saw the value of and need for agriculture and forestry, but in the context of sustainable management.

Far less well-known is Edith Patch. A professor of entomology at the University of Maine in the early decades of the twentieth century, Dr. Patch became the first woman president of the Entomological Society of America. She predicted that, because insects are so important to agriculture and in nature, by the year 2000 there would be "insect gardens" across the United States.

Where were you educated? Cornell University, where I earned a BS in natural resource management and masters degrees in entomology and teaching.

Endangered Species Chocolate Partners with Xerces

The Xerces Society is honored to announce that it was selected by Endangered Species Chocolate to participate in the company's 10% GiveBack program. Through this program, Endangered Species Chocolate donates 10 percent of net profits to organizations that support species conservation, habitat preservation, and humanitarian efforts. Xerces will be a 10% GiveBack partner for the next three years.

Although not directly related to this partnership, Endangered Species Chocolate included Xerces in a social media campaign, "Vote New Faces for New Flavors," to select two animals to be featured on new flavors of chocolate bar. Six candidates were in the running: bumble bee, monk seal, orangutan, peacock, red panda, and wallaby. The decision was based on voting that was done through the company's Facebook page.

The fantastic news is that Xerces was one of the two winners; a bumble bee will become a new wrap star, and Xerces has received a $1,000 donation. This was possible because of a huge outpouring of support; in the end, the bumble bee got well over eighteen thousand votes.

Thank you to Endangered Species Chocolate for including the bumble bee and Xerces in this campaign. Congratulations to the Marine Mammal Center of Sausalito, California, whose monk seal, the other champion, will also be appearing on a chocolate bar.

Endangered Species Listing Proposed for Taylor's Checkerspot

In October 2012, in response to a petition from the Xerces Society and partners, the U.S. Fish and Wildlife Service proposed to list the Taylor's checkerspot butterfly (*Euphydryas editha taylori*) as endangered and to designate critical habitat. Populations of this butterfly have dropped steeply over the past decades; an endangered species listing will protect both it and the prairies in the Pacific Northwest that it calls home.

The native prairie Taylor's checkerspot relies upon is one of the rarest ecosystems in the United States, with 90 to 95 percent of it lost over the past century and a half. The surviving prairies con-

tinue to shrink due to agricultural and urban development, and their habitat value is degraded by changes in vegetation and the spread of invasive plants. The listing proposal includes setting aside some 6,900 acres as designated habitat in Washington and Oregon.

The Xerces Society has been engaged in conservation of this species for more than ten years. (See the article beginning on page 16 in this issue of *Wings*.) We will continue to work with partners, as well as to advocate for the full recovery of Taylor's checkerspot.

Bumble Bee Watch Web Site to be Launched This Summer

This summer the Xerces Society, in collaboration with the University of Ottawa, Wildlife Preservation Canada, and the Montreal Insectarium, will be launching Bumble Bee Watch, a citizen-science initiative to track all species of North American bumble bees.

This project will help us to follow the status of these essential pollinators and inform effective conservation actions. With our new web site you will be able to upload photographs, use an interactive identification tool, and submit records of bumble bee sightings.

If you'd like to be on the mailing list to be notified when the web site goes live, please sign up at bumblebeewatch.org. Until the web site is launched, you can submit bumble bee sightings via email to bumblebees@xerces.org.

Protection Requested for the Rusty Patched Bumble Bee

The Xerces Society filed a petition with the U.S. Fish and Wildlife Service in January, requesting Endangered Species Act protection for the rusty patched bumble bee (*Bombus affinis*). In developing the ESA petition, staff of Xerces' endangered species program worked closely with Dr. Robbin Thorp, professor emeritus at the University of California–Davis and nationally recognized expert on bumble bees, and Elaine Evans, a doctoral candidate at the University of Minnesota.

The rusty patched bumble bee was once very common from the Upper Midwest to the East Coast and was an important pollinator of crops and wildflowers. Recently it has undergone a precipitous decline; a study from the University of Illinois estimates that the bee has disappeared from 87 percent of its historic range. The remaining populations are small and isolated, and are threatened by diseases from a largely unregulated commercial bumble bee industry, as well as by disease from other sources, habitat degradation, pesticide use, and climate change.

The cause of the rusty patched bumble bee's decline has not yet been fully determined. The leading hypothesis suggests that a fungal pathogen was introduced from Europe by the commercial bumble bee industry in the early 1990s, and then spread to wild pollinators. The hypothesis is supported by the timing, speed, and severity of the decline; a crash in laboratory populations of bumble bees occurred shortly before researchers noticed a number of species of formerly common bumble bees disappearing from the wild. In related bumble bees that also are declining,

researchers at the University of Illinois have recently found higher levels of a fungal pathogen and lower levels of genetic diversity. It is noteworthy that the rusty patched bumble bee was too scarce in the landscape to be included in these analyses.

With Endangered Species Act protection, the bee's habitat could be enhanced, and remaining populations could be protected from site-specific threats. Additionally, protection under the ESA may lead government agencies to address issues such as the registration of new pesticides that may be harmful to this species, and the movement of commercial bumble bees, which may transfer disease to wild bumble bees.

Promoting Ecologically Sound Mosquito Management

A new report released by the Xerces Society shows that public education and targeted mosquito management efforts are the best way to protect communities from mosquito-borne diseases and protect wetland health. *Ecologically Sound Mosquito Management in Wetlands* reviews the history of mosquito management in the United States, and describes current practices and their direct and indirect impact on nontarget wildlife. More than 450 publications were reviewed while preparing this report, which also identifies effective ways to manage mosquitoes through public education, action by local residents, the conservation of mosquitoes' natural enemies, and the use of state-of-the-art GIS surveillance.

Insecticides are the default mosquito-management tool in most areas, and each year tens of millions of acres of wetlands are treated with pesticides. The most commonly used pesticide chemicals are organophosphates and pyrethroids, broad-spectrum toxins that severely impact nontarget invertebrates, fish, amphibians, and birds, including endangered butterflies that live near treated areas. Pesticides that target immature mosquitoes are considered less damaging, but even these can have a negative impact on the wetland community by harming nontarget animals and disrupting local food webs.

The report's recommendations follow the principles developed by the Centers for Disease Control, which stress the importance of reducing mosquito abundance through site management and the removal of artificial containers in which these insects can breed. Public education about eliminating breeding sites around the home and taking personal protective measures has been shown to be an effective way to decrease the risk of mosquito bites.

Protecting our remaining wetlands is critical: nearly half of U.S. states have lost more than 50 percent of their wetlands, and several have lost more than 80 percent. It is increasingly important to develop wetland management techniques that sustain the integrity and biodiversity of these vulnerable ecosystems, while simultaneously providing effective management of an insect with public health and nuisance impacts. *Ecologically Sound Mosquito Management in Wetlands* will help land managers formulate site-specific mosquito-management plans that balance the needs of the environment with those of the human community, creating solutions to mos-

Wetlands are critical habitat. The Xerces Society's new report shows how to protect them during mosquito-management activities. Photograph by Celeste Mazzacano.

quito issues that are more effective and at the same time less toxic to the aquatic ecosystem.

The report can be downloaded from our web site, www.xerces.org; printed copies are also available for purchase.

2013 Joan Mosenthal DeWind Award Recipients

The Xerces Society is pleased to announce the winners of this year's Joan Mosenthal DeWind Awards. Each year, Xerces awards two small grants to support innovative studies that advance the science of conservation of butterflies and moths; the grants are named for Joan Mosenthal DeWind, an accomplished amateur lepidopterist and a pioneering member of the Xerces Society.

Rachel Glaeser, of Washington State University at Vancouver, won an award for her project, "Consequences of selective-herbicide use on butterfly populations: evaluating the magnitude and persistence of negative herbicidal effects on the demography of a lycaenid (*Glaucopsyche lygdamus columbia*)." This study will examine the effects of a grass-specific herbicide on the Columbia silvery blue. Egg laying and caterpillar survival will be measured in the field, and a complementary laboratory investigation will evaluate mechanisms by which herbicides might deter butterfly egg laying. The outcome of this research can be used to improve spraying regimes, particularly those implemented in habitat

of endangered butterflies.

The second award goes to John Schroeder, of Stanford University, for his study "Conservation genomics of the checkerspot butterfly, *Euphydryas editha*: finding genes responsible for dispersal propensity." Habitat destruction results in the isolation of habitat patches and associated butterflies, which can interrupt metapopulation dynamics of colonization and extinction. Reintroduction of at-risk butterflies may be necessary to supplement or even replace the natural process of recolonization. This project seeks to determine the genes responsible for dispersal propensity, which can then be used to select a subset of the source population for reintroduction.

From Bees to Birds: Assessing the Impact of Insecticide Use

Last spring, Xerces released *Are Neonicotinoids Killing Bees?* which summarized all available peer-reviewed research on the impact of neonicotinoid pesticides on bees. Since that time we have worked to improve risk assessment for bees and to educate farmers and others on how to limit the impacts of these products. We have also pushed to have the Environmental Protection Agency re-evaluate these chemicals.

Neonicotinoids, now one of the most widely employed classes of pesticides in this country, are highly toxic to honey bees and bumble bees. Corn seed treated with neonicotinoids is planted on millions of acres annually in the United States. Moreover, these products are regularly used around our homes and schools at significantly higher rates (potentially thirty-two times as great) than those approved for agricultural crops. There is mounting evidence that neonicotinoids—especially imidacloprid, clothianidin, and thiamethoxam—are harming bees as well as a variety of other wildlife.

As part of the effort to educate lawmakers and regulators at the EPA about the severe impacts of these chemicals, the Xerces Society partnered with the American Bird Conservancy and the Center for Food Safety to conduct a Senate staff briefing in Washington, D.C., titled "From Bees to Birds: Assessing the Impact of the Nation's Most Widely-Used Insecticides." The briefing was held at the request of the Senate Environment and Public Works Committee and Senator Boxer of California and was attended by eighty people, including

Xerces executive director Scott Black testifying at the U.S. Senate staff briefing about neonicotinoids earlier this year.

staff from numerous Senate offices. Xerces executive director Scott Black highlighted deficiencies in the EPA's current pesticide registration process and stressed key areas that Congress needs to focus upon to resolve these problems. Xerces staff followed up the briefing with meetings with staff from the Senate and House Agricultural Committees and with the EPA.

The goal is to speed the re-registration process for these chemicals. Specifically, we are asking the EPA to reassess the bee safety of currently approved uses of products containing neonicotinoids and to suspend immediately all conditional registrations until we understand how to manage the risk to bees. We are also asking the agency to significantly speed up the registration review process. The EPA should not wait three to five years to make these decisions.

Rising International Shipping Costs Affect Member Discounts

In January, the U.S. Postal Service dramatically increased its international postage rates. The increase is so great that, unfortunately, we can no longer offer discounted merchandise to our international members; this includes Canadian residents. Our online store has been updated to reflect the new prices for international shipping. If you live outside the United States and plan to order books by mail, we ask that you please order via our online store and submit payment for the current international price of the item.

Please also note that payment by Visa or MasterCard is preferred for international merchandise orders. We bank with a Portland-based community bank that charges $20 per item to deposit a foreign check or money order, even if the check is in U.S. funds. Thank you for understanding.

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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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The prolegs on the underside of this woolly bear caterpillar help it grip any surface, but they are a temporary feature. The prolegs are lost during metamorphosis to the adult Isabella tiger moth (*Pyrrharctia isabella*). Photograph by Elise Fog.

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On the cover: Metamorphosis, the process by which an insect transforms from an immature form to a fully developed adult, is a beautiful and fascinating thing to witness. It is not without risk, however, as the insect must remain immobile and vulnerable for long periods during the process. This molting grasshopper was photographed in Suriname by Piotr Naskrecki.