WINGS

ESSAYS ON INVERTEBRATE CONSERVATION

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CONTENTS

Sea Anemones: Flowers of the Sea

Susan J. Tweit

If there is poetry in my book about the sea, it is not because I deliberately put it there, but because no one could write truthfully about the sea and leave out the poetry.
—Rachel Carson,
accepting the National Book Award for *The Sea Around Us*, 1952

I was perched on the bench seat of a *panga*, a deep-sided fisherman's skiff with a powerful outboard engine—a vessel of the sort that is common transportation on the Sea of Cortez—catching up on my journaling while my students, a group of creative writers from around the United States, were taking a break to snorkel. Part of my attention was on the wet-suited and swim-finned bodies rocking in the swells around the buoy where the *panga* was moored, and part was on my writing, when Raoul, our boatman, exclaimed, "*Mira*, Susan! *Flores del mar!*" and pointed over the gunwales.

I looked over the side into the clear azure water. A school of hundreds of

Anemones are carnivorous animals, closely related to corals and jellies. They get their color from algae that live within their bodies. Green anemone (genus *Anthopleura*), photographed by Bill Bouton.

Rocky shores offer habitat for anemones and other marine life, and, at low tide, provide opportunities for people to observe these otherwise hidden creatures. Photograph by Kathy Hall.

colorful fish flickered past and suddenly circled, producing a swirl of sparkling air bubbles. Then I saw what Raoul was pointing at. Among the rocks protruding from the white sand bottom clearly visible perhaps twenty feet below was a cluster of sea anemones, or *flores del mar*, "flowers of the sea." No ordinary sea anemones, however. They were huge, with flat central disks as big as my face, and colored bright greenish-blue, with rows of petal-like tentacles that looked the size of my fingers. On their fat stalks they swayed ever so gently with the swells, mimicking the motion of the *panga* overhead.

"*Son gigantes!*" I said. "How big do you think they are?"

Raoul held his hands out in a circle about the size of a dinner plate.

"Wow," I replied. As we watched, the center anemone in the cluster burped. Its flower-like central disk convulsed, the center drawing in as if to swallow itself, and the fringe of tentacles disappearing into its mouth. A moment later, a white fragment of something flew out, the tentacles reappeared, and the disk rearranged itself back into a placid underwater blossom.

Sea anemones get their name from that deceptively lovely, flower-like appearance. But the name of their phylum, Cnidaria—literally, "nettle-like creatures"—is a better clue to their character. These anemones are no meek garden flowers. In fact, they're not even plants at all; they are carnivorous animals, closely related to jellies and corals. In the adult stage of their lives, sea anemones are sedentary, or nearly so, attached to the ocean bottom or to some solid object underwater by the suction-cup-like disk at the bottom of the fleshy cylinder that comprises most of the body.

The top of a sea anemone's column is what appears flower-like: the flat oral disk with a slit-shaped mouth at its center, surrounded by several rows of those petal-like tentacles. The gently waving "petals" are actually potent armaments. Each tentacle is tipped by a nematocyst, a capsule that explodes on contact, expelling a sticky, thread-like dart studded with venomous barbs that embed themselves in the flesh of whatever touches them. The barbs carry a neurotoxin powerful enough to stun or kill small animals such as crabs, fish, sea urchins, and shellfish. They're not generally large enough to pierce human skin; still, the poison may cause a tingling or sticky sensation.

Sea anemones "hunt" by sitting patiently, their seemingly innocuous tentacles open wide. When a smaller creature such as a sea urchin carelessly walks across the anemone or a fish brushes the tentacles, the nematocysts release their stinging barbs, stunning the prey. Like a flower closing with the night, the tentacles quickly fold inward, bearing the food to the anemone's mouth. Once inside, the meaty parts are digested in the animal's bag-like stomach, and any inedible shell or bones are heaved back out of the mouth slit with a very human burping motion.

Most anemones cluster in colonies of dozens or hundreds, but the *flores del mar* that Raoul pointed out were not numerous enough to call a colony—just three huge specimens with thick, bumpy-skinned stalks. They were almost certainly giant green anemones, which are among the world's largest, found from Alaska to Panama attached to rocky substrates in locations ranging from nearshore tidepools to waters fifty feet deep.

Giant green anemones are often solitary creatures, but, in the vicinity of such dense aggregations of food as mussel and sea urchin beds, these huge anemones may crowd together to benefit from the foraging of predatory sea stars, commonly called starfish. A sea star strolling into an urchin bed, for instance, provokes an underwater stampede; as the spiny creatures try to escape their many-armed predator, some invariably rush directly into another peril: the tentacles of giant green anemones. Also, sea stars are messy eaters, dropping chunks of meat and shell that anemones can snag.

Giant green anemones get their startling coloration from other invertebrates that live in their tissues. When these anemones live where there is sufficient sunlight, minute algae—either bright green unicellular zoochlorellae or yellow-brown dinoflagellates called zooxanthellae—take up residence in the anemones' digestive tracts. Both types of algae make chlorophyll and synthesize their own food from sunlight. Some of the food they produce leaks through their cell walls and into

Despite the variety in color, these sea stars belong to a single species, the ochre sea star (*Pisaster ochraceus*). Sea stars are messy eaters, dropping chunks of food that can nourish nearby anemones. Photograph by Kawika Chetron.

their hosts, akin to what happens with lichens, where a food-producing alga feeds the fungus within whose tissues it resides.

What is not clear is whether the anemone-algae relationship is similar to that of the fungus and algae that make up lichens, where the non-photosynthesizing fungus, which cannot survive on its own, essentially captures and enslaves free-living, photosynthesizing algae as a food source. Like the species of algae in lichens, the algae of sea anemones can and do survive on their own, but giant green anemones apparently also can exist without their algal partners, although then they grow more slowly than they otherwise would. Zooxanthellae have a similar relationship with coral, except that, for these reef-forming ocean creatures, the food produced by the tiny algae is crucial—without it, they die. Coral "bleaching," the loss of color and subsequent death of coral in ocean reefs, happens when the sugar-making zooxanthellae are killed by overly warm ocean water, as is happening as a consequence of global climate change.

Despite their stinging tentacles, sea anemones are vulnerable to predators. Some nudibranchs—brightly colored mollusks often called seaslugs—graze the tips of the tentacles and then ingest the nematocysts, which lodge, in perfect working order, at the ends of the nudibranchs' tubercles, soft "spines" protruding from their backs. The nudibranchs then use the nematocysts in their own defense.

Other predators simply crawl or saunter up to an anemone's succulent column and begin to feed. Wentletrap snails — small snails with long-spiraled shells — secrete a violet-colored toxin that acts as an anesthetic, numbing the tissues before they begin chewing. Sea spiders — tiny crustaceans that look like minute, scrawny crabs — are not so subtle: they sink their sharp proboscises into the anemones' soft flesh and suck their juices.

That morning off Baja California, I watched the huge green anemones on the sea floor below, hoping to see what they were eating, until the *panga* swung away and I lost them from view.

"Whenever I go down into this magical zone of the low water of the spring tides," wrote Rachel Carson in *The Edge of the Sea*, "I look for the most delicately beautiful of all the shore's inhabitants — flowers that are not plant but animal, blooming on the threshold of the deeper sea." Strange flowers indeed: they live underwater, sting with their petals, house algae within their tissues, and eat meat.

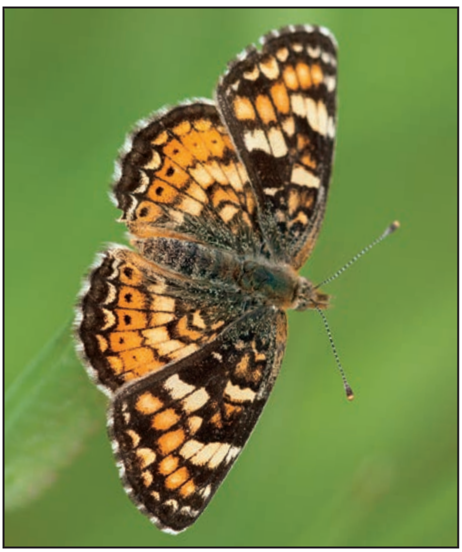
This article is adapted from Seasons on the Pacific Coast: A Naturalist's Notebook, *Chronicle Books, copyright © 1999 by Susan J. Tweit. A plant ecologist who turned to writing when she realized that she loved telling the stories behind the data more than collecting the data itself, Tweit explores the relationship between "human" and "nature." She has written twelve books as well as hundreds of newspaper columns, articles, essays, and radio commentaries. She also teaches writing workshops and maintains a widely admired blog, "Walking Nature Home."*

Nudibranchs are among the few animals that eat anemones. They browse the stinging tips of an anemone's tentacles, which they ingest and transfer to the ends of their own tentacle-like tubercles. *Dendronotus iris*, photographed by Keoki Stender.

Butterfly Monitoring: On Being in the Right Place at the Right Time

Arthur M. Shapiro

Over lunch at a Nepali restaurant in California, I sat down with two colleagues, Florian Altermatt from Switzerland and Chris vanSwaay from the Netherlands, to discuss the organization and politics of monitoring butterflies for conservation. My research group had received widespread attention in the American print and broadcast media after we published a paper in the *Proceedings of the National Academy of Sciences* demonstrating significant declines in Californian butterfly faunas over the past thirty-five or so years. Using a battery of statistical approaches, we interpreted those declines in terms of changes in both climate and land use.



The field crescent (*Phyciodes campestris*) has disappeared from almost all of the author's monitoring sites. Photograph by Ann Thering.

In the highly charged American political climate, this resulted in a lot of bizarre and very nasty things being said about me online by people who had never heard of me until a few minutes before. My European friends are not used to such abusive rhetoric. While Europe has its own political problems, even right-wing extremists generally acknowledge the consensus of climate scientists that the planet is warming, and biologists whose data appear to support that consensus are not subject to ridicule and vilification.

In a growing number of European countries, butterfly-monitoring programs are in place to detect and quantify effects of environmental change. The situation is painfully different here. The mere fact that our paper made so many waves is testimony to that difference: it drew a lot of attention precisely because so little long-term data are available on this side of the Atlantic. That dearth makes my data set, which is now entering its thirty-ninth year, that much more valuable, but the gathering of that information did not begin as an extended monitoring project.

What started as a short-term effort to identify the most important climatic variables affecting butterfly seasonality at a handful of sites has evolved into

Four decades of monitoring butterflies along a transect from California's Sacramento Valley to the Sierra Nevada has yielded a wealth of data that is only now beginning to be understood. Common sootywing (*Pholisora catullus*), photographed by Bryan Reynolds.

a permanent, ten-site transect right across north-central California. It embraces nine thousand feet (nearly twenty-eight hundred meters) of elevation, and includes the entire set of Merriam "life zones" from Upper Sonoran to Arctic-Alpine (with climates and vegetations to match) and more than 150 species and subspecies of butterflies. I do all the data collection myself, visiting each site at roughly two-week intervals throughout butterfly season, ranging from at least forty-four weeks in the lowlands to as little as fourteen weeks above treeline. That adds up to roughly 220 days a year in the field. Of course, I do other things too, including teaching on average six courses a year and training graduate students. But any dermatologist who looked at my face would immediately conclude that I was either a farmer or a sailor. The time for benefiting from sunscreen is long past.

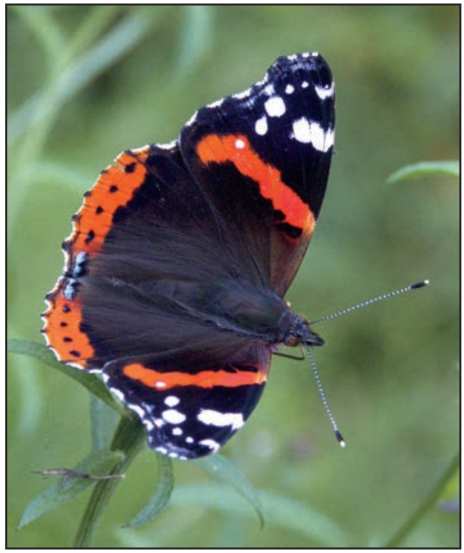
And here we are, with a butterfly database of nearly forty years, one of the two largest and oldest in the world! (The other is the British Butterfly Monitoring Scheme, founded about the same time, but created as an open-ended monitoring program.) The data set is not perfect, but despite its limitations it has told us a lot. Not all of what we've learned relates to climate change, but most of it is not good news. After decades of denying that butterfly populations were declining, I've been forced by the data to admit that right in my own back yard they are going downhill.

Some things are obvious to the unaided eye. The large marble (*Euchloe ausonides*) and the common sootywing (*Pholisora catullus*) used to be very common here; now the first is regionally extinct and the second nearly so. The sylvan hairstreak (*Satyrium sylvinus*) used to swarm over dogbane and milkweed flowers in riparian habitat in the Sacramento Valley; now it's gone, or nearly so. But much of what has happened over thirty-eight years is much more subtle, so subtle that it needed statistics — what one of my political detractors derisively called "statistical gibberish"— for us to get at the truth. Our data required several years of careful work to extract the hidden secrets. We assembled an outstanding team, headed by my former student Matt Forister, now at the University of Nevada, Reno.

So what *did* we find? I'll provide a brief synopsis here, with the qualification that further analyses are in progress and further conclusions are to be expected in the next couple of years, as more data come flooding in.

First, we found that of twenty-three common butterfly species studied near sea level, sixteen are emerging earlier in spring than they did in the 1970s, and two of these, the red admiral (*Vanessa atalanta*) and the sachem (*Atalopedes campestris*), are emerging three weeks earlier than they used to. (Strikingly, the red admiral is the butterfly most phenologically responsive to climate change in Britain, and the sachem has also expanded its range on the West Coast northward into Washington and Idaho and eastward into Nevada.) The remaining seven species are emerging later. Several of these seven are declining, with the field crescent (*Phyciodes campestris*) and the purplish copper (*Lycaena helloides*) in freefall. In fact the field crescent is now extinct at all but one of my sites, and it is on shaky ground in the one place where it still can be found.

It's also the case that emerging earlier is not necessarily a good thing. In



Monitoring programs in both California and Britain indicate that the red admiral (*Vanessa atalanta*) is changing its flight period in response to climate change. Photograph by Henk Wallays.

Europe, Florian Altermatt found that longer growth seasons are allowing some butterflies and moths to add a generation late in the season. In lowland California, most of our ruderal butterflies — species that thrive where the natural vegetation has been disturbed by humans — have several generations through the season, becoming progressively more abundant with each generation and reaching peak numbers in autumn. Then, depending on the winter, they undergo more or less severe overwinter mortality before starting over the following spring. An extra round of reproduction late in the season can cause all kinds of problems. Many of these species have winter dormancy (diapause) in the larval or pupal stage, which is triggered by a combination of day length and temperature. A reset reproductive calendar can lead to miscues, such that dormancy actually sets in *earlier* than before—as seems to be happening with the anise swallowtail (*Papilio zelicaon*)—or it fails to happen at all, leaving the last generation unprepared for winter.

We have not yet looked for advancing first-flight dates at higher elevations, where the timing of snowmelt is critical. But there, synchronization with host-plant growth is a serious concern. At Donner Summit in 1992, for example, the snowpack was very poor, April was quite warm, and May was warmer than a normal June. Most species emerged weeks early, and an early-June snowstorm killed most of the caterpillars. Those stragglers that emerged after the snow had melted reproduced at more or less the normal time, but the vegetation was already very advanced and had dried up altogether by midsummer, causing large-scale larval mortality. This was an isolated catastrophe, but it's easy to see such occurrences becoming more or less the norm as global warming continues.

Second, we found that butterfly faunas in the Sacramento Valley are deteriorating rapidly, particularly over the past decade. Not only are species being completely lost, but many others are becoming less abundant. These trends are not well explained by climate, and the inevitable conclusion is that some factor other than climate is the prime factor here. When we examined land use, based on county-level data, bingo! Not only is land use changing—from butterfly-friendly rural to butterfly-sterile urban and suburban—but rapidly spreading development seemingly leapfrogs natural areas and destroys habitat connectivity, making it considerably more difficult for dispersing gravid females to find patches of usable habitat.

Sachem butterflies (*Atalopedes campestris*) in the Sacramento Valley are now emerging nearly three weeks earlier each spring than they were in the 1970s. Photograph by Bryan Reynolds.

We were initially flummoxed at the sudden deterioration of our lowland ruderal butterfly fauna — species such as the large marble and the common sootywing — that had long ago accommodated to human activity, breeding happily on naturalized exotic weeds. But when we began analyzing along the entire transect, a broader, hitherto unsuspected pattern emerged: in fact, the ruderal fauna was declining *faster* than was the non-ruderal. This seemed counterintuitive. But in fact there does appear to be a significant loss of habitat for these species, and an even more significant disruption of habitat connectivity. As their numbers dwindle in the lowlands, there are fewer individuals available to move upslope and colonize the mountains in the summer.

Finally, at the highest elevation, near and at treeline, climate-driven change is obvious. The incidence of upslope dispersal by non-ruderal, mid-elevation species has increased significantly. Many of these cannot breed in the subalpine and alpine zones because their hostplants are not there — *yet*. In general, plants shift distributions more slowly than butterflies, so butterflies cannot colonize until their plant resources do. Overall species numbers recorded in the subalpine and alpine zones are trending upward, unlike any other sites on my transect. At the same time, three of the four most characteristic alpine species (and I hasten to add they are not restricted to alpine habitats everywhere) are declining, two of them — the Nevada skipper (*Hesperia nevada*) and the small wood-nymph (*Cercyonis oetus*) — dramatically.

The alpine fauna faces a grim fate if warming continues. Here in California we have various alpine species — insects, other animals, plants — that occur disjunctly in the Sierra Nevada from the Donner Pass area southward and, in the

Rapidly spreading urban areas have diminished habitat for many butterflies, including the purplish copper (*Lycaena helloides*). Photograph by Ann Thering.

Butterflies that live in the mountains, such as the small wood-nymph (*Cercyonis oetus*), may be worst hit by climate change. Photograph by Kim Davis and Mike Stangeland.

far northwest part of the state, in the high country of the Klamath-Siskiyou-Trinity-Eddy mountains. We infer on various grounds that, when the Pleistocene glaciers receded, these species followed cold climates upslope to the summits. In the intervening lowlands north of Donner (punctuated by two young volcanoes, Mount Lassen and Mount Shasta) climates became too warm and perhaps too dry for them, and they died out, leaving populations in the two alpine regions of the state. As climates continue to warm, the zone of inhospitable climate will march upslope, pushing these species off the summits and into oblivion. As I put it to the press, "They'll have nowhere to go but Heaven."

That, in a nutshell, is what we have extracted so far from thirty-eight years of data. These are our conclusions about the past. Predicting the future, of course, is fraught with pitfalls. The most dramatic effects, those associated with land use, are almost certainly based on human activity. The more subtle ones associated with climate change are just becoming evident. This is all quite far from what I started out to look for nearly forty years ago when I arrived as a very green assistant professor out here at the West Pole, and I would be happy to learn that the data were misleading me. But they're not.

Arthur M. Shapiro has been chasing butterflies since he was a child in Pennsylvania, a pursuit that led him through college and eventually to the University of California at Davis, where he has worked for nearly four decades. He is currently a professor of entomology, evolution, and ecology. Since 1977, in an annual competition, he has awarded a pitcher of beer to the first person each spring to catch a live cabbage white butterfly.

The Beautiful Katydids

Piotr Naskrecki

The male stops singing and lifts his body high above the surface of the palm leaf on which he stands. His body shifts almost imperceptibly toward a large shape in front of him. A female has finally arrived, attracted by the loud bursts of high-frequency calls that he has broadcast from his perch for the last couple of nights. She is definitely interested in him, but the deal is by no means sealed. All the energy he has expended on calling, and the dangers he has exposed himself to by revealing his location to the entire world, are nothing but a prelude to the true test that will determine whether his genes are passed on to the next generation. In most animals the arrival of the female signifies her willingness to mate, and her wooer is more than happy to oblige. Katydid males, however, are far more discerning than most, and he is almost as likely to reject her as she is to reject him. In many katydids, the male's investment in offspring is nearly as significant as that of the female, and, not surprisingly, he wants to place it with the best partner possible. Females who are deemed too small or too weak to be good mothers will be unceremoniously spurned.

On the leaf, the female spotted sylvan katydid (*Scopiorinus impressopunctatus*) extends her long antennae toward those of the male, and for a few minutes the pair "smell" each other with their long appendages. Suddenly, still silent, the male forcefully shakes his entire body, sending a series of low-frequency waves through the leaf toward the female. She responds in the same fashion, and for a while the pair continue

The globular white mass at the base of the female katydid's swordlike ovipositor is the spermatophylax, the nutrient-rich gift from the male. Photograph by Piotr Naskrecki.

This southern African species, *Clonia melanoptera*, a predator, uses its large, spiny legs to catch its prey. Photograph by Piotr Naskrecki.

to exchange short, silent vibrations. Satisfied with her strength and size, the male does not retreat. As the female approaches, he lowers his body and slides under her, firmly grabbing the tip of her abdomen with a pair of short processes on his; he then secures her position on top of him by crossing his long hind legs over her back. For the next few hours the pair remain connected, while the male produces a complex gelatinous structure, which he carefully attaches to the base of the female's ovipositor, her egg-laying organ. Then, after the pair finally separate, the female doubles up and begins eating it.

This nuptial gift, known as the spermatophylax, represents a major investment on the part of the male and is the reason why the male katydid is often as coy as the female in selecting a mating partner. The spermatophylax contains not only his sperm cells, which ensure fertilization of the eggs, but also a large packet of carbohydrates and proteins, which nourish the female. In some cases, the weight of this nuptial gift may exceed 20 percent of the male's body weight and constitutes an enormous contribution to the fitness of the potential progeny. It has been shown that a large nuptial gift significantly increases the body size—and thus the survival potential—of the offspring. Of course, not all katydid males produce huge nuptial meals; in some species, the only function of the spermatophylax is to keep the female busy removing it, with the hope of reducing the chances of her mating with another male.

Katydids, known in Britain and Europe as "bush crickets," are classified as the superfamily Tettigonioidea of the order Orthoptera. They are related to

Translucence allows this sylvan katydid (*Mustius superbus*) to blend with the leaf. Photograph by Piotr Naskrecki.

crickets and grasshoppers, but differ from them in a number of important characteristics. Nearly all species of katydids produce sound by rubbing the base of the left wing against the right one. Crickets employ a similar technique, but one that involves a different part of the wing, whereas grasshoppers usually sing by rubbing their hind legs against their wings or abdomens. Katydid songs can be extremely loud. In North America, the robust conehead (*Neoconocephalus robustus*) produces a call with the intensity of 116 decibels, a sound louder than a lawnmower or a jackhammer, although a large part of its energy is inaudible to human ears because of its high frequency. Many species produce calls that greatly exceed our hearing capabilities, often reaching frequencies above 100 kilohertz—the upper range for the most sensitive of human ears is about 22 kilohertz—and some entomologists speculate that the main function of such high-pitched calls may be to interfere with the echolocation of bats, the katydids' principal enemies. In any case, luckily for us, courtship calls of many North American species can be enjoyed even by those whose high-frequency perception is past its prime.

Late-August evenings in rural New England tend to be hot and sticky, and if you close your eyes it is easy to believe that you are in some remote tropical location. Mosquitoes reinforce this feeling, but if you brave that minor unpleasantness you may be rewarded with one of the most beautiful aural landscapes on the North American continent. Among the multitude of bell-like tree crickets and buzzy cone-headed katydids, one sound is sure to stand out and make an unforgettable impression on your senses—the otherworldly, loud, and steady staccato of the true katydid (*Pterophylla camellifolia*). But despite the ubiquity of its acoustic presence, finding the singer is not an easy task. True katydids usually sing from high perches, often twenty to thirty feet above the ground, and their green, cryptic coloration makes spotting a singing male difficult. If you are persistent, though, and lucky, you will be rewarded with the sight of a large, beautiful insect that looks like something that came from the steamy rainforests of South America. And, in fact, it probably did.

The North American true katydid is a member of the lineage known as sylvan katydids (the subfamily Pseudophyllinae), a group of insects that flourishes in the tropics and includes some of the most spectacular examples of plant mimicry in the animal kingdom. One tropical species in particular, the peacock katydid (*Pterochroza ocellata*), takes its resemblance to a dried, damaged leaf to the extreme. No two individuals are alike in their color or even the shape of the wing, a mechanism adapted to prevent such predators as birds and monkeys from learning to recognize them as a potential meal. This polymorphism fools not only predators, but also some taxonomists. A recent study demonstrated this unequivocally when twelve previously recognized "species" of the genus *Pterochroza* were identified among the offspring of a single female!

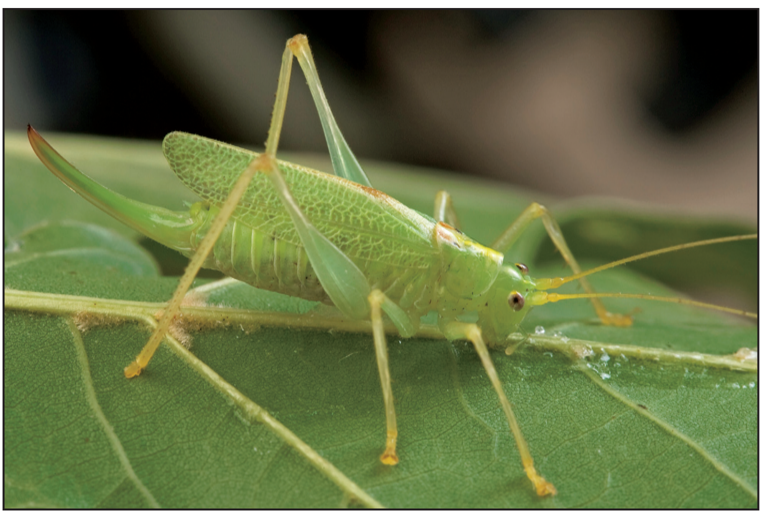
For decades, ethologists — scientists who study animal behavior patterns — have used a handful of katydid species as model organisms to study and understand processes that govern mate selection and parental investment, but we know shockingly little about the lives of the vast majority of the more than sixty-seven hundred known species. In addition, there are probably two to four thousand species awaiting discovery and description; virtually every recent, comprehensive regional study anywhere in the world revealed faunas of katydids of which 30 to 75 percent of species were new to science. Even in the United States, where the katydid fauna is relatively well known, new species are discovered with some regularity. About 280 species have been recorded from the continental United States — Hawaii has its own endemic genus, *Banza*, with eleven species — but new kinds are still being found in the southern regions of the country. In some groups, such as the coneheads (*Neoconocephalus*), studies of their acoustic behavior reveal the presence of "cryptic species," types that are virtually indistinguishable on morphological grounds but are reproductively isolated and different in their behavior.

Unfortunately, as new species are being discovered, we are losing others. Katydids are one of the few groups of North American invertebrates in which the extinction of species has been un-

Many katydids have remarkably realistic camouflage. The peacock katydid (*Pterochroza ocellata*) resembles dead leaves; other species mimic green foliage. Photograph by Piotr Naskrecki.

ambiguously demonstrated, as exemplified by the now-extinct Antioch Dunes katydid (*Neduba extincta*). As with most invertebrates, habitat loss is the main culprit, but North American katydids may face additional dangers. In many meadows of the northeastern United States you are less likely to encounter any of the native shield-backs (*Atlanticus*) than you are an invasive Roesel's katydid (*Metrioptera roeselii*). This aggressive, predaceous species came from Central Europe, probably sometime at the beginning of the last century, and has been spreading like wildfire along the East Coast and steadily moving west. Although nobody has yet looked at the actual impact of this species on local katydids, the fact that it hatches and matures earlier in the season than local species do — and then feeds on young nymphs of other species — is bound to have serious implications for the native fauna. Woodlands of the Northeast are also full of another European arrival, the oak katydid (*Meconema thalassinum*). It is a small, pale-green species, whose males are unusual for their inability to sing, choosing instead to attract females by drumming against tree bark with their hind legs. In some places, including my own garden near Boston, this outsider is now the only species found.

Although the general perception of katydids is that of green, leaflike, and rather dull herbivores, across the globe they have evolved into a multitude of shapes, sizes, and lifestyles. In southern Africa, giant predatory katydids (*Clonia*) spread their muscular, spiny legs to catch cicadas and beetles, while in the forests of Costa Rica rhinoceros katydids (*Copiphora rhinoceros*) prey on snails and lizards. In Australia, pollen-feeding katydids (*Zaprochilus*) extract nectar and pollen from the flowers of trees and bushes; and in Tibet the black *Hyphinomos* ekes a living among patches of ice sixteen thousand feet (forty-nine hundred meters) up in the



The oak katydid (*Meconema thalassinum*) is a European species now well established in North America. Photograph by Piotr Naskrecki.

This katydid (*Hetrodes pupus*) is well protected by the armored plates on its body, but if those fail it sprays the attacker with its own bitter blood. Photograph by Piotr Naskrecki.

Himalayas. The diversity of shapes among species of katydids, such as the sticklike *Phasmodes* and the armored, tanklike *Hetrodes*, is so great that it is hard to believe that these insects are members of the same lineage. But this is what makes them such interesting subjects of research. We know, based on both morphological and genetic data, that they are all closely related to each other, and we can now trace the historical and evolutionary forces that shaped their bodies and behaviors.

Ecologists use katydids to assess the level of habitat disturbance, often applying methods that rely solely on the unique acoustic signatures of each species, and physiologists tap into their nervous systems to understand the nature of hearing. Ethologists continue to disentangle the intricate rules of their courtship in order to explain what lies behind the often mysterious choices of mating partners, and biochemists have just begun to discover potent chemical defenses present in some species. Katydids are beautiful and fascinating animals that in many ways help us understand the world around us. It would be nice to repay the favor by making sure that we allow them to continue their very existence.

Piotr Naskrecki is a research associate at the Museum of Comparative Zoology at Harvard University, where he works on the evolution and systematics of orthopteroid insects. He is also involved in a number of invertebrate-conservation projects, including the IUCN Red List assessment of African katydids and the development of internet-based identification tools and resources for invertebrate biologists and conservation practitioners. As a writer and photographer he strives to promote the beauty, value, and conservation of invertebrate animals.

Appropriate Forest Management In the Face of a Bark Beetle Epidemic

Scott Hoffman Black

When I was growing up in Nebraska, my family often made trips to the Rocky Mountains. Images of jagged peaks, swift cold rivers and streams, and pine forests are still vivid in my mind. Millions of green trees blanketed the steep slopes and valleys. Visiting Colorado last year, I was shocked to see that in many places these have been replaced by what appears to be a ghost forest, due to a very large and perhaps unprecedented outbreak of bark beetles. Formerly green hillsides are now brown with dead and dying trees.

There are more than six thousand species of bark beetles worldwide, with about five hundred species in North America. Most species cause little or no

When bark beetle numbers grow too large, even healthy trees can succumb to their attacks, leaving a landscape in which many of the trees are dead or dying. Lodgepole pine forest in Colorado photographed by Whitney Cranshaw, courtesy Bugwood.org.

Natural enemies of bark beetles such as insect-eating birds, predatory beetles, and parasitic wasps help to limit outbreaks. Red-bellied woodpecker photographed by Johnny N. Dell, courtesy Bugwood.org.

economic damage, normally infesting stumps and downed woody material or standing trees that are either dead or severely weakened. The beetles usually reproduce on an annual cycle. During the summer, adults emerge from their host trees and fly to new ones. Once there, they burrow into the bark and, if successful, find mates and create egg-laying tunnels. The larvae spend several months feeding on the phloem—the inner layer of bark through which sap flows, rich with sugar and nutrients—emerging as adults the following summer. As they eat, the larvae bore intricate networks of tunnels, forming galleries under the bark. Different species create different patterns.

These beetles have been part of Rocky Mountain forests for millennia. Despite their apparently devastating impact, they play an important role in the development of forest ecosystems by shaping the habitats used by other wildlife. They are a key part of many forest food webs, providing sustenance for insect-eating birds such as woodpeckers, serving as prey for spiders and predatory beetles, and acting as hosts for parasitic wasps. Feeding beetles create snags that may be used by woodpeckers, owls, wrens, nuthatches, and chickadees, as well as by such mammals as bats, squirrels, American martens, Pacific fishers, and lynxes. Dead trees that fall into creeks are essential for creating pools that provide habitat for trout. The beetles also function as nutrient recyclers, agents of disturbance, and regulators of forest productivity, diver-

No larger than a grain of rice, bark beetles can cause big problems for trees. Adults emerge during the summer and, prior to mating, fly to new trees where their larvae take up residence under the bark. Mountain pine beetle (*Dendroctonus ponderosae*), photographed by Whitney Cranshaw, courtesy Bugwood.org.

sity, and tree density, all of which help maintain the dynamic conditions that support a broad variety of forest plants and animals.

But, as important as these insects are, the fact remains that they are capable of killing large numbers of trees. A few species of beetles, such as those of the genus *Dendroctonus*, normally exist as small populations that feed mainly on trees that have recently died. Healthy trees are strong enough to overcome the presence of bark beetles at normal population levels. The first line of defense is "pitching." As the beetle begins to tunnel into a tree, large amounts of resin push it back out, leaving it entombed in a sticky lump. But, when conditions are right, beetle populations can grow rapidly. Beetles launch pheromone-mediated attacks, producing chemical signals that attract other beetles in such numbers that they overwhelm the defenses of even healthy trees. The result is the dead and dying forests that we now see throughout western North America.

There is no single simple reason that a population of bark beetles reaches epidemic levels, but the warming climate, particularly in the last few decades, appears to have played a major role in recent insect outbreaks. Warm and dry conditions are important to increasing infestations in the Rocky Mountains; such conditions not only stress host trees and make them less able to defend against beetles, but they can also accelerate the growth of beetle populations, in part because milder winters reduce seasonal mortality.

In addition to climate, forest structure can be an important contributing factor in beetle outbreaks. The current epidemic of bark beetles is to some extent possible because vast areas of forests provide suitable habitat for them. In particular, lodgepole pine is afflicted by the mountain pine beetle (*D. ponderosae*), and mixed forests of Engelmann spruce and subalpine fir are suffering from incursions of the spruce beetle (*D. rufipennis*).

Many people are rightfully concerned about these infestations. The dead trees, of course, change the face of the landscape, and some people worry that the large amount of standing dead material will lead both to a greater number of forest fires and to fires that are more severe, perhaps threatening nearby houses and neighborhoods. As a result, many decision makers and land managers are rushing to promote logging and thinning in affected areas.

To understand the issues and look for potential solutions, I recently worked with Dominik Kulakowski of Clark University, Barry Noon of Colorado State University, and Dominick DellaSala of the National Center for Conservation Science and Policy to review the relevant science and produce a report on the impacts of bark beetles upon fire in forested ecosystems and the efficacy of potential measures for controlling outbreaks.

Although it is widely believed that beetle outbreaks set the stage for severe forest fires, the majority of research does not support this supposition. Evidence from several studies, including those of Dominik Kulakowski, shows that climatic conditions appear to have an overriding effect on fire regimes in forests of lodgepole pine and mixed spruce and fir—so much so that changes in fuels brought about by outbreaks of bark beetle have little or no effect on fire occurrence, extent, or severity.

Some policy makers have asserted that logging of forests may be a remedy to stop bark beetle outbreaks, but the facts just do not support this claim. Despite nearly a hundred years of active forest management to control the mountain pine beetle, there is very little evidence that logging is effective once a large-scale insect infestation has begun. Thinning of forests has also been suggested as a preventive action to control future outbreaks by alleviating some water stress on trees during dry spells, which in turn might help them better withstand infestation. But for thinning to be effective it would have to reduce water stress significantly, an unlikely outcome during the severe droughts that are associated with most outbreaks. Moreover, under favorable climatic conditions, such as those of the past decade, outbreaks of bark beetles

Healthy trees can repel bark beetles by expelling them with resin before they burrow in too deeply. Photograph by Whitney Cranshaw, courtesy Bugwood.org.

Of the approximately five hundred species of bark beetle in North America, most cause no problems for forests. Red turpentine beetle (*Dendroctonus valens*), photographed by Whitney Cranshaw, courtesy Bugwood.org.

often erupt simultaneously in numerous stands across the landscape; even if the resistance of one stand of trees were strengthened, beetles from other stands are likely to spread over an entire area.

The logging of beetle-killed trees—often referred to as "salvage" or "post-disturbance" logging—can actually lead to *heightened* insect activity, both by reducing parasites and predators of the beetles and by creating greater stress on the remaining trees through damage to bark and roots. And logging can have a profoundly negative impact on these forest ecosystems by disturbing wildlife populations and impairing water quality. It has also been shown to seriously damage soil and roots by compacting them, leading to greater water stress and increased susceptibility to insects and disease. Thus, although there may be economic benefits from utilizing some of the dead trees that are now abundant in the landscape, there is really no ecological justification for logging them.

Given that neither logging nor preventive thinning is likely to prevent major infestations due to the overriding influence of climatic stress in driving outbreaks, what should we do? If the goal is to protect communities, fire-mitigation efforts should be focused on those areas closest to communities and homes, and not on remote and ecologically valuable areas. If the goal is to protect human lives and property from the dangers of fire in nearby trees, then we should ensure that there is *strategic* removal of hazard trees where they may harm life and property. Focusing such efforts around communities is much less expensive, far more effective at reducing risk, and less damaging to ecological values.

We also need to remember that, although the current insect outbreaks are extremely large—and may even be unprecedented in recent history—there is strong evidence that affected forests will regenerate in time. Some areas are losing many trees and I may not be able to see the landscapes of my youth again during my lifetime, but green forests will eventually return in most locations. Until that time, the landscape that surrounds us may appear different, but beetle-affected forests are nonetheless functioning ecosystems that provide food and shelter for animals, and cool, clear water for fish, other wildlife, and humans.

Scott Black is the executive director of the Xerces Society.

The Great Sunflower Project

Gretchen LeBuhn

As you sit at your table today, do you know where the water you're drinking came from? In San Francisco, 85 percent of drinking water comes from the Sierra Nevada Mountains. How about the last prescription medicine you took? Of the top 150 prescription drugs used in the United States, 118 originate from natural sources. Three-quarters of these come from plants and a fifth from fungi. The remaining few percent come mostly from bacteria, though 2 percent are from snake venom! And where did the ingredients for your lunch and dinner come from? One of every three bites you took probably came from a plant pollinated by an insect. The good news is that this is just the beginning of the list of ecosystem services, benefits provided to human society by healthy, natural ecosystems. Pollination, for example, is a valuable ecosystem service that contributes greatly to human health and livelihood. It is provided in the main by a multitude of insects, though hummingbirds and a few species of bats help in North America, and elsewhere a smattering of other birds and mammals — even lizards on some islands — support the work of insects.

As readers of *Wings* know, however, the not-so-good news is that scientists

The Great Sunflower Project has thousands of people across North America growing sunflowers and watching to see how many bees visit them. Photograph by Tim Schleicher.

think some pollinator populations are in jeopardy. Bumble bees in both the United States and Great Britain are disappearing, and the widespread losses of honey bees from Colony Collapse Disorder have been regularly reported in the media. And these declines may not be restricted to particular species; a 2007 report from the National Academy of Sciences suggests that they may be broad in scope. The problem is that no one knows just how pervasive the declines are, nor does anyone know what effect these declines are having on pollinator services to plants. No one knows because there has never been a survey at a large enough scale to understand what's happening in North America.

Economists and ecologists have begun working together to find a way to place a monetary value on the contribution of natural ecosystems to human existence. The estimates are eye-opening. For example, one recent calculation of the value of pollination services worldwide is $217 billion per year. Replacing the benefits of natural pollination — the portion of these services currently provided by wild insects at no cost — would be a daunting task, costing many trillions of dollars. By carefully planning and managing human-dominated landscapes, however, valuable ecosystems and their services can be conserved.

We know that pollinators are declining, but we know virtually nothing about the effect these losses have had on pollination services, particularly in urban and suburban areas. We do not know the magnitude of the crisis, nor have we identified how and where to target our conservation measures in these areas. Such information is particularly important for efforts such as community gardens. Worldwide, community gardens provide 10 to 15 percent of the food supply. For the urban poor, such a garden may provide 60 to 80 percent of a family's food, and it can be the only way for a woman to make an economic contribution to the family.

Unfortunately, a continent-wide survey of pollination services cannot be undertaken using traditional scientific methods. The research infrastructure that would be required to survey pollinators and pollination services at countless individual sites is prohibitively expensive, the scale just too vast. The Great Sunflower Project, however, offers an alternative approach. By using citizen scientists across the continent, each surveying pollinators in his or her own back yard or local park or community garden, we can gather the necessary data to inform our understanding of pollinator declines while providing our participants with the ability to put the pollination services in their own immediate environments into a local, regional, and even continental context. Although most citizen science projects simply list the number of species found at a site, we believe that citizen scientists can be very effective at surveying complex ecological processes such as pollination. Imagine knowing enough to say, "Wow, my garden has many more pollinators than most of my neighbors and most of San Francisco, but fewer than average for the Bay Area."

The Great Sunflower Project is designed to extend understanding in just this way. The process is not complicated: citizen scientists record how many bees visit their sunflower over a fifteen-minute period, effectively generating an index of pollinator service.

A wide range of bees visit sunflowers. Male longhorn bee (*Melissodes robustior*) photographed by Rollin Coville.

Project participants can also take photographs of the visiting bees and upload them to the project's website. To create a standardized barometer, the same variety of sunflower, Lemon Queen, is used at every site, and to ensure that the data are comparable between locations, certain conditions must be met. The weather should be warm and sunny and the observations made in the morning, preferably around ten o'clock. The observer should only record bees visiting newer flowers that are actively producing nectar or pollen. Using Geographic Information Systems, we can combine these data with information about pesticide use, changes in land use, and locations where honey bees have disappeared. Ultimately, this effort will allow us to identify areas where pollination services are low and thus target efforts at pollinator conservation.

Launched in 2008, the Great Sunflower Project was an immediate success. Within a week of my sending out a few emails asking for volunteers, more than ten thousand people had signed up. Within two months, there were twice as many. Now, in 2010, more than seventy-five thousand sunflower gardeners have joined the project. Although we began in California, there are presently citizen scientists in all fifty states and every Canadian province and territory. We have had a large response from retired people, home-schooled children, teachers, community gardeners, nature centers, beekeepers, and parents looking for a family project. While our focus has been on the scientific benefits, we relish the opportunity to get children outside to watch processes unfold in the natural world; in 2009, the Great Sunflower Project was endorsed by the Forum on Children and Nature as one of the top thirty projects for getting children into nature. And it is a pleasure to increase scientific literacy by sharing with participants how research projects are designed, teaching them how to collect data, and providing them with online tools to understand and analyze the data they collect.

We expect three outcomes from this effort. First, we hope to create a detailed map across towns, cities, states, and countries (and, eventually, continents), identifying the areas that do not have adequate pollinator services. Second, we will have a digital record of pollinators visiting sunflowers, allowing us to understand where honey bees are not providing pollinator services and to see whether and where native bees are replacing them. Third, we are creating a community of citizen scientists, helping to raise awareness about ecosystem services, pollinators, and the threats they face. In finding a way to track and value the pollination services provided by nature, the Great Sunflower Project is a step toward a sustainable future.

Gretchen LeBuhn is an associate professor of biology at San Francisco State University. Her work focuses on both the evolutionary ecology of plants and the conservation of their pollinators, including, in particular, research into the effects of climate change on alpine bumble bees and the effects of urbanization on wildlife.

Lemon Queen is the sunflower grown by all participants in the Great Sunflower Project. Photograph by Elizabeth Smith.

XERCES NEWS

Bark Beetles in Western North America

As highlighted in the article beginning on page 20, forest die-off associated with bark beetles is a major concern across western North America. A recently released report, *Insects and Roadless Forests: A Scientific Review of Causes, Consequences, and Management Alternatives*, suggests that bark beetle outbreaks will not lead to greater fire risk, and that tree thinning and logging is not likely to alleviate future epidemics of bark beetles. The report also indicates that tree cutting in roadless forests is unlikely to keep houses safe from wildfire. Findings from the report apply to millions of forest acres of lodgepole pine and mixed spruce and fir across North America.

The report was written by Xerces executive director Scott Black; Dominik Kulakowski, professor of geography and biology at Clark University in Massachusetts; Barry Noon, professor of wildlife ecology at Colorado State University; and Dominick DellaSala, president and chief scientist of the National Center for Conservation Science and Policy. The report can be downloaded from the Xerces Society's website.

Pollinator Conservation Strategy for Yolo County

The Yolo Natural Heritage Program recently released the *Yolo Natural Heritage Program Pollinator Conservation Strategy*. This first-of-its-kind conservation strategy, written by Xerces Society scientists, provides policy makers and land managers with information vital to securing the future of pollinators in California's Yolo County.

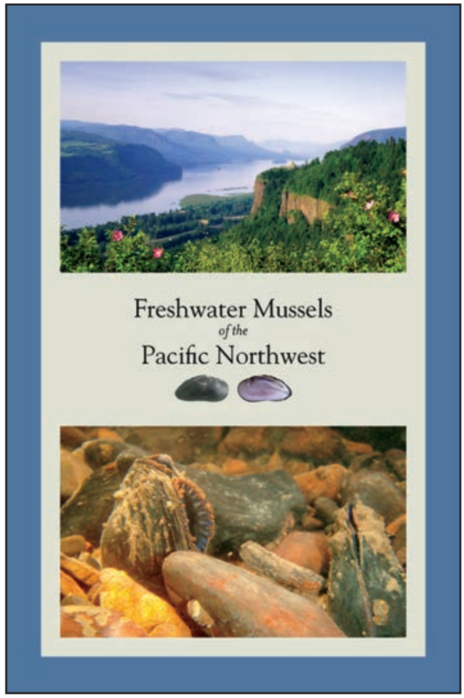
Each of the six major landscapes in the county—agricultural, grassland, woodland, shrubland and scrub, riparian and wetland, and urban and barren—are affected by threats to native pollinators. The strategy summarizes these threats and identifies conservation measures that can be taken to protect pollinators. Although written for a specific county in California, the threats and strategies discussed are relevant for other states. The report can be downloaded from our website.

New Resources for Pollinator Conservation Online

The Pollinator Conservation Resource Center on our website offers a wealth of information about protecting and providing forage and nesting habitat for bees and other pollinating insects. Now lists of suppliers of native plants and seeds have been added for each region of the United States, making this the most comprehensive source for advice about pollinator conservation.

Also new to the website is a page about organic farming and bees. Although organic farming is widely considered to be good for the environment, it is not without impact, and our Organic Farming Toolkit offers factsheets and guidelines, including *Organic Farming Practices: Reducing Harm to Pollinators from Farming*; *Organic-Approved Pesticides: Minimizing Risks to Pollinators*; and *Tunnel Nests for Native Bees: Nest Construction and Management*.

An Expanded Field Guide to Freshwater Mussels



The Xerces Society has recently published the second edition of *Freshwater Mussels of the Pacific Northwest*, by Ethan Nedeau, Al Smith, Jen Stone, and Xerces endangered species program director Sarina Jepsen. This field guide provides an introduction to freshwater mussels west of the Rocky Mountains.

The expanded publication discusses the anatomy, life cycle, habitat, ecosystem role, diversity, distribution, human use, and management of freshwater mussels. It also offers updated information on the status and taxonomy of western freshwater mussels and a detailed bibliography. A profile describes each mussel, where it occurs, and its life history and habitat needs, and provides conservation guidance.

To purchase a paper copy of this guide, or to download it at no charge, please visit our website.

Protecting Bumble Bees and a Stonefly

Recent work by Xerces Society staff and Dr. Robbin Thorp of the University of California at Davis has established that at least four species of North American bumble bees are in steep decline; two of these species teeter on the brink of extinction. A major threat is the spread of diseases from commercially reared bees shipped throughout the United States.

In January, the Xerces Society submitted a citizen petition to the U.S. Department of Agriculture's Animal and Plant Health Inspection Service requesting a ban on the movement of bumble bees outside of their native ranges and, for interstate movement within their native ranges, a requirement that bumble bees be certified as disease free. The petition, submitted in collaboration with Defenders of Wildlife, the Natural Resources Defense Council, and Dr. Thorp, was supported by more than sixty scientists, including the world's top bumble bee experts.

The Society also led a coalition of scientists and conservationists to request that the U.S. Fish and Wildlife Service extend Endangered Species Act protection to the Arapahoe snowfly (*Capnia arapahoe*). Known from only two small tributaries of the Cache la Poudre River in the Front Range of northern Colorado, the Arapahoe snowfly is critically imperiled. Threats come from a variety of activities that impact the creeks and their water quality. These include livestock grazing, logging, erosion from roads, pollution from insecticides and septic systems, stream de-watering, and mountain-biking trails that cross and re-cross the creeks.

Snowflies (sometimes called winter stoneflies) require cool, clear rivers and streams, and are excellent biological indicators of watershed health. Protection under the Endangered Species Act would ensure careful management not only to sustain the Arapahoe snowfly but also to maintain the diversity of wildlife that this watershed supports.

2010 DeWind Award Winners

The Xerces Society congratulates the 2010 winners of the Joan Mosenthal DeWind Awards, given annually to university students who are engaged in research that will further the conservation of butterflies and moths.

Lindsay Crawford (University of Western Ontario) will investigate how habitat fragmentation and butterfly genetics interact to influence survival of the threatened bog copper (*Lycaena epixanthe*) in southern Ontario.

Jill Sherwood (Iowa State University) will study how climate change affects interactions between the Clodius parnassian (*Parnassius clodius*) and its caterpillar hostplant, *Dicentra uniflora*, a species of bleeding heart.

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The shapes and colors of nudibranchs vary greatly, and many have a surreal, otherworldly appearance. But don't let the beauty deceive. These marine mollusks are carnivores, feeding on sponges, hydroids, and anemones—and even on their own species. Spanish shawl (*Flabellina iodinea*), photographed by Keoki Stender.

Many katydids mimic leaves—usually with amazing fidelity—in order to conceal themselves. When discovered, though, some species can startle predators to give themselves a chance of escape. Our cover photograph shows a peacock katydid (*Pterochroza ocellata*) in full display; page 17 shows it in camouflage mode. Photograph by Piotr Naskrecki.