Sonorensis

Arizona-Sonora Desert Museum

Our SONORAN DESERT *Insects*

2010

Sonorensis

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Co-founded in 1952 by
Arthur N. Pack and William H. Carr

Craig Ivanyi
Executive Director

Christine Conte, Ph.D.
Cultural Ecologist

Richard C. Brusca, Ph.D.
Senior Director, Science and Conservation

Linda M. Brewer
Editing

Wendy Moore, Ph.D
Entomology Editor

Martina Clary
Design and Production

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Visit us at www.desertmuseum.org

Cover: Flame skimmer *(Libellula saturata)*. Photo by Katja Schulz.

Back cover: Oak leaf grasshopper *(Tomonotus ferruginosus)*. Photo by Alex Yelich.

Thanks to all the photographers who contributed photos for this special issue of Sonorensis, especially Alex Wild and Katja Schulz.

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photo by Alex Wild

photo by Alex Wild

photo by Larry Jon Friesen

C O N T E N T S

photo by Alex Wild

Photos: Milkweed longhorn beetle (Cerambycidae); ox beetles *(Strategus* sp.), female (left) and male; male giant water bug *(Abedus* sp.) with eggs on his back. Cut out photo: Major and minor workers of the Arizona turtle ant *(Cephalotes rohweri)*.

Our SONORAN DESERT INSECTS | Introduction

Christine Conte, Ph.D.
Cultural Ecologist, Arizona-Sonora Desert Museum

The real voyage of discovery consists not in seeking new landscapes but in having new eyes.

—Marcel Proust

Each year, *Sonorensis* brings the Museum's conservation science team and its colleagues in the community to your doorstep with thoughtful, engaging, and informative perspectives on the natural and cultural history of the Sonoran Desert Region.

Often inspired by comments and questions from members and visitors, we've explored a range of topics over the past decade, including large-scale conservation challenges like invasive species, ecosystems of the Santa Cruz River and the Sea of Cortez, the gustatory pleasures and health benefits of local foods (and production techniques that support a healthy environment), and an in-depth look at the charismatic jaguar and the people working on both sides of the U.S.-Mexico border to ensure its survival in the wild.

In this issue, we focus on insects of the Sonoran Desert Region. Though small in body size, their impacts on the ecosystem and on us are enormous. Life as we know it would not be possible without them. In these pages, you'll become acquainted with their astounding diversity, stunning beauty, unique attributes and adaptations, and the many ways they benefit plants, wildlife, and people.

It is little wonder that in almost every culture, throughout world, insects have played a prominent role in philosophy, psychology, and religion. They have been portrayed as symbols of gods and celebrated in stories, songs, literature, and art. Here in the Sonoran Desert, the ancient Hohokam depicted insects on pottery and used the resinous secretion of a lac insect to adhere turquoise and shell mosaics to shell jewelry. A traditional Tohono O'odham story tells how the Creator made butterflies from all the beautiful colors of nature to brighten the hearts of children.

Insects also underscore the uniquely maritime nature of our Sonoran Desert. Almost all of our monsoon moisture originates as evaporation off the surface of the Sea of Cortez (Gulf of California) during the summer cyclonic wind pattern in the Sonoran Desert Region. Our most spectacular insect emergences coincide with these summer monsoon rains, and many species have their life cycle closely tied to this unique wet season.

We hope you enjoy this encounter with insects you are likely to meet here in the Sonoran Desert and that this issue of *Sonorensis* helps you appreciate them for the miniature marvels they are. S

photo by Alex Wild

Green fig beetle *(Cotinus mutabilis)*

photo by Bernard Siqueiros

Tohono O'odham basket

INSECTS: *Six-Legged Arthropods that Run the World*

Wendy Moore, Ph.D.
Assistant Professor, Department of Entomology, University of Arizona;
Curator, University of Arizona Insect Collection

Carl Olson
Associate Curator, University of Arizona Insect Collection,
Department of Entomology, University of Arizona

Left page: Adult horse lubber grasshopper. Upper left: Purple pleasing fungus beetle *(Gibbifer californicus)*. Lower left: Grant's hercules beetles *(Dynastes granti)*, male (top) and female. Center: Beyer's scarab *(Chrysina beyeri)*. Right: Robber fly (*Megaphorus* sp.).

STAGGERING DIVERSITY

Anyone with a passing interest in natural history has heard that an enormous number of insect species inhabit the Earth. That is true, of course, but the abstraction "enormous number" falls far short of capturing the staggering diversity of insects. Imagine it this way. There are approximately a million described species of insects compared with 58,000 described species of vertebrates (mammals, birds, reptiles, amphibians, and fishes) combined. Even the tremendous diversity harbored in the world's seas is surpassed by the diversity of insects alone in the terrestrial world. In fact, more than three fourths of *all animals* on Earth are insects!

In many ways, insects literally run our world. Not only are insects the most important pollinators of plants, gracing our landscape with flowers and critical to the yield of most of our food crops, they also aerate the soil and are the most significant animal decomposers of dead plants and animals—a much underappreciated but essential function in the regeneration of life. (Without decomposers, the soil would lack nutrients that plants need to grow, and dead organic matter would quickly accumulate.) Some insect species, like honey bees and silk moths, have been domesticated for many centuries, providing human societies with treasured delicacies. But the services insects provide don't stop there. In most terrestrial food webs, insects are the most important herbivores and the most abundant food for higher-level carnivores in the ecosystem. Without insects, most land-based ecosystems would collapse into something unrecognizable. In fact, without insects, life as we know it would cease to exist. And yet, they are too often and too easily taken for granted.

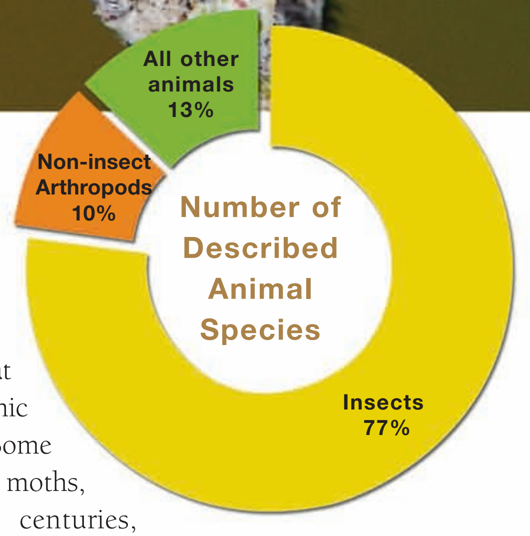

photo by Katja Schulz

Green fig beetle *(Cotinus mutabilis)* eating prickly pear fruit.

photo by Gene Hanson

Tarantula hawks *(Pepsis* spp.) are wasps that feed on nectar and pollen as adults. The larvae feed on tarantulas. After mating, female wasps lure a tarantula out of its burrow by creating vibrations on its silk web. Then the female stings the tarantula, paralyzes it, and drags it to another burrow that she has dug. She then lays an egg on the tarantula's body, which the baby wasp slowly consumes as it matures.

Glorious scarab *(Chrysina gloriosa)*

photo by Alex Wild

THOSE WITH SIX LEGS

Insects comprise the most diverse class of a broader group known as arthropods, which also includes spiders, scorpions, centipedes, millipedes, and crustaceans. Rather than having a skeleton of internal bones to support their bodies, arthropods have a very tough outer skin, called an exoskeleton. Because the exoskeleton is hard and inflexible, in order to grow they must molt. That is, they must shed that tough outer skin and pump themselves up with air to expand their newly exposed skin until it hardens. After the new exoskeleton is firm, the insect expels the air, leaving room for growth inside its new casing.

Insects are unique among arthropods in that they have three pairs of legs. In other words, an arthropod with six legs is an insect; if it has more or less than six, it is not. Insects can be found almost everywhere, from the highest mountains to the edge of the oceans, at the bottom of rushing streams, and in the high canopy of rainforests. A few species even live on the ocean surface, far from land. They burrow through the ground, hop and sing in the trees, and dart and dance in the air. We have only to open our eyes to begin to understand them; but beware, for once you begin to look closely, you just might just fall in love.

MANY PATHS TO SUCCESS

Why are insects such a successful and diverse group? Although biologists have long pondered this question, there doesn't seem to be a single, straightforward answer. But we have identified several factors that, in combination, help to explain their success.

Time Arthropods are a very old group, relative to all other land animals. In fact, arthropods were the first land animals, evolving over 400 million years ago from shrimplike ancestors living in the sea. The insects appeared shortly after arthropods moved onto land, and since that time they have been co-evolving with plants and other land animals at breakneck speed. This 400-million-year-old co-evolutionary dance between insects and other animals and plants has significantly shaped the world as we know it today.

Short Life Span As in all animals, the life cycle of an insect includes its growth from a fertilized egg to sexually mature adult to the generation of

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Tobacco hornworm *(Manduca sexta)*

offspring. Among the million or so known species of insects in the world, there is considerable variability in the length of time it takes to complete this life cycle. Most insect species complete their life cycle in 12 to 24 months, but many have much shorter life cycles (only one or two weeks), while others have much longer life cycles (such as the 17-year cicadas). But, on average, the insect life cycle is relatively short compared with those of other animals. The short time it takes for insects to produce a new generation is another factor in their success, because it speeds up the process of natural selection; they evolve quickly, adapting to new or changing environmental conditions.

Small Size Compared with vertebrates, insects are relatively small. Because of their small size, insects can subdivide and utilize the environment in many more ways than larger animals, and there is a much broader range of ecological niches available to insects. For example, some insects spend their entire adult lives on the body of other, larger insects! Almost any specialized habitat you can think of is home to one, and usually more, insect species. There are insects that live inside of leaves of plants, in brine pools, in hot springs, on glaciers, under leaf litter, and deep underground. Some insects, like the water striders, actually walk on water.

Wings Among major categories of animals, wings are rare. While some fish and squirrels have structures that allow them to glide, only birds, bats, and insects have powered flight. Most insects have wings that allow these lightweight creatures to take advantage of the world in three dimensions. Just how important are wings in the evolution of new species and exploitation of new niches? Well, there are more insect species than any other group of animals; there are more bats than any other group of mammals except rodents; and there are more birds than any other group of vertebrates!

Development Among insects, there is great variability in the method of development—that is, in their physical appearance and their habits during the stages of development leading up to adulthood. The most diverse groups of insects, those that entomologists refer to as the "big four"—beetles (Coleoptera),

photo by Alex Wild

Palo verde root borer *(Derobrachus hovorei)*.

photo by Alex Wild

Giant mesquite bug nymph *(Thasus neocalifornicus)*.

photo by Young Gage

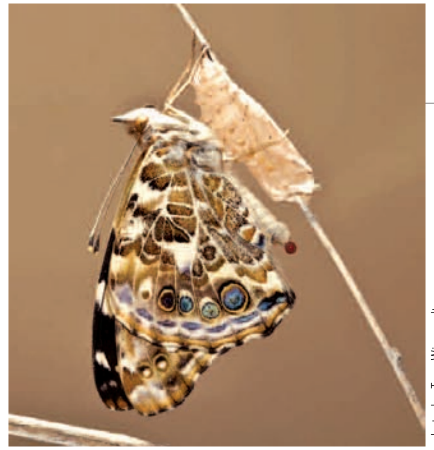

photo by Tom Wiewandt

photo by Rhonda Spencer

Above: California mantis *(Stagmomantis californica)*. Top right: Painted lady *(Vanessa cardui)*. Above right: Pipevine swallowtail *(Battus philenor)*.

photo by Michael C. Thomas

Typhon sphinx moth caterpillar *(Eumorpha typhon)*.

Giant swallowtail butterfly *(Papilio cresphontes)*.

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butterflies and moths (Lepidoptera), bees and wasps (Hymenoptera), and true flies (Diptera)—all go through what is known as "complete metamorphosis." In these groups, their life cycle consists of four distinct phases: egg, larva, pupa, and adult. It is thought that the ability to exploit different environments and food sources during different life stages has given insects greater opportunity to specialize and diversify.

SONORAN DESERT BEAUTIES

Those of us who live in the Sonoran Desert are lucky to be in a marvelous environment for insects. Every year entomologists flock to the Sonoran Desert Region, especially after the onset of the monsoon rains, to collect its spectacular six-legged residents.

Butterflies have probably been the best known and most loved insects throughout human history. Understandably so, since they flutter gracefully though air amid blooming flowers like shimmering fantasies of the imagination. Well represented in poetic literature, their ephemeral elegance (and amazing life history) is indeed inspirational. Not surprisingly, the Arizona state insect is an absolutely gorgeous butterfly, the two-tailed swallowtail *(Papilio multicaudata)*. Butterflies are plentiful in the Sonoran Desert. Here, you can find over 250 species including the pipevine swallowtail *(Battus philenor)*, the queen *(Danaus gilipus)*, the monarch *(Danaus plexippus)*, the sleepy sulfur *(Eurema nicippee)*, and the giant swallowtail *(Papilio cresphontes)* to name just a few.

Other than entomologists, biologists, and the occasional passionate amateur, however, few people care to know much about those insects that are not such stunning showstoppers—that is, until they take a closer look. If we were to elect a signature non-butterfly insect for the Sonoran Desert, it might be a tight race between the giant palo verde root borer *(Derobrachus hovorei)*, the Pinacate beetle *(Eleodes* sp.), the giant mesquite bug *(Thasus neocalifornicus)*, the horse lubber grasshopper *(Taeniopoda eques)*, and the tarantula hawk wasp *(Pepsis formosa)*. All of these large, conspicuous beauties are common in the Sonoran Desert at certain times of the year. And although multitudes of tiny ants, wasps, caterpillars, and flies are less easy to see, they can be equally impressive, especially under magnification.

Because of the hot, dry climate in the Sonoran Desert, insects here have evolved many different ways to prevent overheating and desiccation. Perhaps the most efficient

photo by Margarethe Brummermann

Ghost beetle *(Asbolus verrucosus)*

strategy is evaporative cooling. For instance, the Apache cicada *(Diceroprocta apache)* sucks on the fluids of plants and excretes the excess water through special pores on its back—a system that allows this insect to "sweat" and be active (and incredibly loud) during the hottest parts of the summer day. The ghost beetle *(Asbolus verrucosus)* secretes a thick layer of wax during hot, dry periods to help maintain moisture within its body, and in doing so it turns from black to white, inspiring its common name. Males of the giant water bug (Belostomatidae) continuously move back and forth between water and land so that the eggs, which are laid on its back by the female, are alternately moist and air-dried, a necessity for proper development and hatching. These examples barely touch upon the plethora of fascinating, effective structural designs and strategies that insects—in association with plants and animals—have acquired over their long evolutionary history. Next time you walk in the desert, take time to stop, look, listen, and become aware of the small marvelous wonders all around us. We are truly fortunate to live in an environment where we can be entertained by these marvelous animals. S

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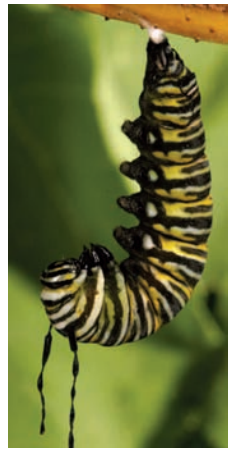

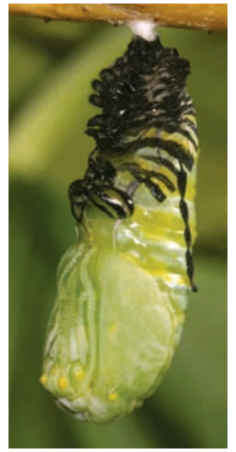

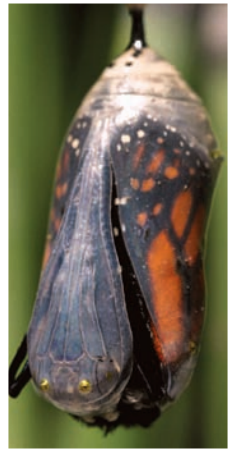

photos by Larry Jon Friesen

In one of the most remarkable migrations on Earth, every fall millions of monarch butterflies make the journey from southern Canada and the United States to a tiny patch of *oyamel* (fir) forest, high on a mountaintop in central Mexico. In the spring, they return north. This annual round-trip covers thousands of miles and requires several generations to complete. Monarchs lay eggs (the bottom photo shows a female depositing an egg; the top photo shows an egg attached to a leaf) that hatch into stunning yellow-black-and-white banded larvae—the caterpillars. Like all members of the butterfly subfamily Danainae, these larvae feed almost exclusively on milkweeds (plants in the genus *Asclepius)* from which they derive cardioglycoside, a substance poisonous to would-be predators that is passed from larva to adult butterfly during pupation. This sequence of photographs shows the life stages of a monarch, from egg, to larva, to pupa, to emergence of the adult butterfly.

photo by Alex Wild

Mark A. Dimmitt, Ph.D.
Director of Natural History, Arizona-Sonora Desert Museum
Richard C. Brusca, Ph.D.
Director, Science and Conservation, Arizona-Sonora Desert Museum

PLANTS & INSECTS: *A 400-Million-Year Co-Evolutionary Dance*

Consider these estimates of the number of species in the world *(the number in parentheses indicates an estimate of the number of species still undiscovered and undescribed):*

Nonflowering plants:	30,000 described (+10,000)
Flowering plants:	250,000 described (+150,000)
Vertebrates:	58,000 described (+10,000)
Invertebrates:	1.3 million described (+10–60 million)

The clear standouts are flowering plants and the invertebrates (about a million of which are insects). Why do these two groups so greatly dominate our planet's biosphere? A major reason is their extensive ecological interactions driven by natural selection, particularly in the realm of pollination ecology.

Land plants appeared in the Paleozoic Era about 435 million years ago (mya), and seed plants emerged much later in that era, during the Permian Period, around 280 mya. The first terrestrial insects appeared in the Devonian Period, 400 mya, and plant-insect symbioses began at least 300 mya (as demonstrated by tree fern galls from the Carboniferous Period). But, the fossil record indicates that from 400 to 190 mya, the number of species of land organisms remained much lower than today. Flowering plants first appeared in the early Jurassic Period (during the Age of Dinosaurs), 190 mya. Soon after their appearance, both flowering plants and insects underwent an explosion of speciation and evolutionary radiation unlike anything previously seen on Earth, resulting in myriad new species with increasingly diverse morphologies.

Like animals, most plants need to "mate" with another individual of the same species in order to produce offspring. But, unlike most animals, plants can't move. Nonflowering plants (gymnosperms such as conifers and "lower" plants such as ferns) mostly depend on wind and water to disperse their gametes (e.g., pollen) in order to fertilize ova on other plants. But, it turns out that pollen is also a protein-rich food, and insects discovered this early on. As they flew from plant to plant in search of sustenance, they unintentionally became efficient transporters of the pollen that stuck to their bodies. And thus a valuable symbiosis was born: the insects get nourishment; the plants get pollinated.

Left page: Green metallic bee *(Agapostemon* sp.) pollinating a flower.

Right: Tobacco hornworm moth *(Manduca sexta)* drinking nectar from a flower of a South American cactus *(Echinopsis shaferi)*, in a Tucson garden.

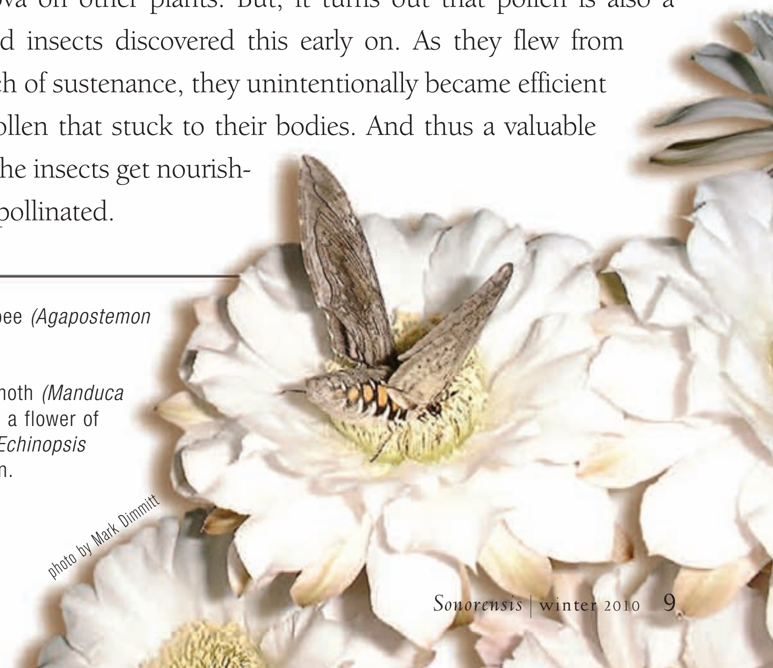

photo by Mark Dimmitt

The earliest flowers were presumably structures adapted to efficiently concentrate the reproductive organs at branch ends, where wind could disperse pollen from male organs, and where female organs could capture that pollen. This concentration of pollen and ovaries created the initial floral attraction for insects (and other animals). Natural selection favored mutations in the flower parts that created better landing platforms for insects, and colors and fragrances that proved attractive to particular species of insect visitors. The result was increasing specialization; certain pollinators came to specialize on, and seek, particular flower forms. The narrower the association between plant and pollinator became, the more efficient the pollen transfer, and consequently the more niches for both animal and plant species in the same physical space. (Many species of plants are pollinated by a single small group of animals, such as "large butterflies" or "cactus bees.")

Once pollination or fertilization has occurred, flowers on some plant species send a signal to insects that their services are no longer needed. For example, in many flowers, within minutes of fertilization, nectar dries up, flower color begins to fade, or the petals change color or droop down. These visual signals send the pollinators to other flowers that still have nectar and that are still in need of pollination.

Another interesting plant-insect interaction has also fostered insect biodiversity—herbivory. Herbivores get their energy by eating plants. In response to this predation, plants have evolved a huge number of bitter and toxic chemicals that deter animals from eating them. Why a huge number? Because herbivorous animals are continually evolving, too, developing tolerances to the toxins. Because of the typically short time span between generations, insect species develop

photo by Wendy Moore

Mexican palo verde flowers *(Parkinsonia aculeata)*. The upper flower has not yet been pollinated; the lower flower has, as indicated by the color change and the droop of the 'banner petal.'

photo by Alex Yelich

A bee *(Megachile* sp.) collecting pollen. Bees are some of the most important pollinators.

resistance more quickly than vertebrates. It's an evolutionary arms race. Plants develop new toxins; insects develop new antidotes. In the race, though, most insects drop by the wayside; few species can adapt to all toxins of all plants. The result is that out of the tens of thousands of herbivorous species that might occur in a given region, most plants have only a few insects that can eat them. And therein lies another source of specialization leading to increased biodiversity: an insect that has resistance to a particular plant's toxins secures for itself a nearly exclusive food source (while the plant can survive the limited herbivory from this one or few species of insects). As an example, one common desert plant, the creosotebush *(Larrea divaricata tridentata)*, has some 60 species of insects that are specifically associated with it. But you'll probably never see one of these shrubs heavily impacted by insect herbivory, because only a few of those insects are adapted to actually consume creosotebush. The arms race is in balance.

Humans derive many benefits from the insect-plant chemical arms race. Many of the toxins plants have invented are metabolic poisons, which in small doses have turned out to be useful pharmaceutical drugs. Although most of the natural toxins are eventually synthesized in the laboratory, about three-fourths of our medicines were first discovered in plants. The next time a prescription drug restores your health, you might well thank the 400-million-year co-evolutionary arms race between plants and insects. And it isn't only drugs. The delicious flavors that we call spices and herbs are due to the phytochemicals that also evolved to protect the plants from herbivores. We have many reasons to rejoice in the diversity and evolutionary history of insects and flowering plants! S

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FIT TO BE EATEN: A Brief Introduction to Entomophagy

Marci Tarre
Adjunct Faculty, Pima Community College

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Although most of us probably find the thought of eating insects totally foreign, if not repulsive, distasteful, or at least a little challenging, insects have long been an important source of food for people around the world. In fact, a report by Julieta Ramos-Elorduy in 1991 noted that various life stages of over 1,000 species of insects grace the plates of both the rich and the poor in over 65 nations. Insects offer nutritional, medicinal, and flavor benefits to those who indulge in them, and some insect-eaters aver spiritual benefits. They are plainly an abundant, free resource with great potential for sustainability, and here in the Sonoran Desert, we are blessed with dozens of edible insect species. The Tohono O'odham and other indigenous Sonoran Desert dwellers traditionally ate some of these species. Other species were (and still are) eaten in southern Mexico, and other parts of Central and South America. Still other species present in the Sonoran Desert Region are known as food insects only in faraway countries. Whether their entomophagous (insect-eating) history is from here or overseas, these locally occurring insects deserve recognition and consideration as foodstuff by creative, forward-thinking consumers.

BENEFITS of Entomophagy

Nutritionally speaking, insects are a valuable source of essential amino acids as well as many other vital nutrients. Some contain high levels of proteins and fats as well as iron, zinc, thiamin, riboflavin, iodine, vitamin A, magnesium, calcium, and dietary fiber. (A study of edible caterpillars from Zaire shows them to contain all the essential vitamins except B1 and B6 for proper growth in young rats.) The quality of lipids in insects is usually quite good as well; many insects contain omega-3 fatty acids, the very stuff now sold in health food stores as a cure-all for everything from depression to hypertension. And unlike red meat, they offer a high ratio of unsaturated fatty acids to saturated fatty acids.

TRADITIONAL & CONTEMPORARY Entomophagy in the American West and Mexico

Until relatively recently, indigenous people of present-day Mexico and the United States relied upon and celebrated the culinary use of insects, and some of these insects continue to be accepted as food in parts of Mexico. In the Mexican states of Oaxaca, Guererro, Morelos, and Veracruz, a "salsa" is made with crushed stink bugs *(Euschistus crenator)*, locally referred to as *jumiles*. *Jumiles* are also eaten in traditional tacos. These stink bugs and other species of the same genus have an aromatic and deep flavor, described as minty or cinnamonlike. But they are more than just a good taste; stink bugs contain between 36 and 59 percent protein.

Ancient Mexicans also extracted oil from pentatomids (like stink bugs and shield bugs) to treat various tubercular diseases. Live pentatomids are considered powerful analgesics and anesthetics against toothache as well as rheumatic and arthritic pain. They are also considered useful in treating gastrointestinal diseases. They contain large amounts of iodine and are used by rural people of Guererro, Mexico, to treat Graves' disease, an autoimmune deficiency disorder that affects the thyroid gland.

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Fried grasshoppers for sale at market in Oaxaca, Mexico.

Some Edible Sonoran Desert Insects

Say's stink bug (adult)	*Chlorochroa sayi*
giant mesquite bug (nymph and adult)	*Thasus gigas*
Apache cicada (adult)	*Diceroprocta apache*
locusts (nymph and adult)	*Schistocerca* spp.
slant-faced grasshoppers (nymph and adult)	*Boopedon* spp.
house cricket (nymph and adult)	*Acheta domestica*
velvety tree ants (larva, pupa and adult)	*Liometopum apiculatum*
leafcutter ant (larva, pupa and adult)	*Atta mexicana*
honey bee (larva and pupa)	*Apis mellifera*
paper wasp (larva and pupa)	*Polistes major*
white-lined sphinx moth (larva)	*Hyles lineata*
corn earworm (larva)	*Heliothis zea*
greater wax moth (larva)	*Galleria mellonella*
agave weevil (larva)	*Scyphophorus acupunctatus*
mealworms (larva)	*Tenebrio* spp.
house fly (larva)	*Musca domestica*
beetles (larvae) in the family Buprestidae	
beetles (larvae) in the family Scarabaeidae	

Photo by Bill Hornbaker

Photo by Chip Hedgcock

Left: White-lined sphinx moth caterpillar. Right: White-lined sphinx moth caterpillars roasted and on sticks.

Photo by Manny Rubio

White-lined sphinx moth *(Hyles lineata)*.

Another insect food source in central and southern Mexico is a species of ant *(Liometopum apiculatum)* whose immature queens are eaten by people in the states of Michoacan, Pueblo, and Zacatecas. These ants are approximately 80 percent protein; they also surpass the United Nation's Food and Agriculture Organization's recommendations for many essential amino acids.

Grasshoppers have been a major food resource in many countries over the centuries. They are, or were, reportedly eaten in more than 35 countries worldwide, including the United States. In the Great Basin of eastern California, Native Americans of the Washoe culture traditionally collected grasshoppers and roasted them over a fire. Roasted grasshoppers could be eaten plain, stored away in bulk, strung on sticks, or ground into a highly nutritious flour to be combined with other foods. The Washoe ate many different species of grasshoppers, taking advantage of this ready source of protein (grasshoppers range between 52 and 72 percent protein). People inhabiting the region around the Great Salt Lake of Utah also ate several species of grasshopper, including those in the genera *Melanoplus* and *Anabrus*. Here, huge swarms of migrating grasshoppers were periodically blown into the salty water, where they drowned. When the salted grasshoppers washed up on the shore, they cured naturally in the sun, and local Utes and Paiutes harvested them by the thousands by simply strolling along the shoreline with baskets.

Grasshopper nymphs and adults are, or were, also eaten in several states of Mexico. Red-legged grasshoppers *(Melanoplus femurrubrum)*, and spur-throated grasshoppers *(M. ponderosus)* have been marinated in lemon juice and spiced with salt and chile in southern Mexico. In the southern Mexican state of Oaxaca, grasshoppers in multiple genera (including *Sphenarium, Boopedon, Taeniopoda,* and *Melanoplus)* are cooked in chile and lime and are widely sold in markets and restaurants today as *chapulines*. Like grasshoppers, Mormon crickets *(Anabrus simplex)* were an important part of the diet of indigenous peoples in the western United States. They, too, were roasted for a nutritious meal in the warm seasons.

At one time, cicadas were a traditional food for the riverine Pima, and possibly the Pima Bajo, Tohono O'odham, Maricopa, Western Apache, and others. One member of the Navajo Nation reports that Navajo also ate these insects, as he did as a youngster. Today, cicadas are eaten by people in Thailand, in Hidalgo (Mexico), in Amazonia, and by Aboriginal people of Australia. All benefit from the high protein content of cicadas—a hefty 72 percent or more!

In addition to cicadas, the O'odham routinely ate tiny bruchid beetles along with the mesquite pods they inhabit. In fact, there is no distinct word for the beetles in the O'odham language; they share a name with mesquite pods. They also ate white-lined sphinx moth caterpillars *(Hyles lineata)*, as did indigenous people throughout North America (apparently including Cahuilla, Navajo, Seri, Pyramid Lake Paiute, Southern Paiute, Washoe, Western Shoshone, and Ute peoples).

WHITE-LINED SPHINX MOTHS & the Tohono O'odham

White-lined sphinx moth caterpillars, and the moths they become, are large insects associated with natural desert vegetation. Adults of these and related species are often called "hummingbird moths" because they hover around tube-shaped flowers to take nectar with their long proboscis (tongue). Sphinx moth caterpillars are often called "hornworms" because of the spine protruding upward from their posterior end. Known as *makkum* by the O'odham People, these caterpillars are bright yellow or green with longitudinal black stripes and lateral red dots. Fully grown, they are about three inches in length. *Hyles lineata* eggs hatch during the summer monsoons, after which the caterpillars forage gregariously on low-growing vegetation, with a preference for spiderling plants in the four o'clock family *(Boerhavia* sp.). When they are ready to pupate, they leave the plants to search for soft dirt in which to bury themselves.

Tohono O'odham men, women, and children collected *makkum* during the caterpillar's wandering pre-pupation phase. After removing the head and viscera, the larvae were traditionally roasted over hot coals and either eaten immediately,

photo by Alex Wild

Worker ants *(Liometopum apiculatum)* in alarm posture. The immature queens of this species are savored in some Mexican communities.

photo by Mark Dimmitt

Red spiderling plant *(Boerhavia coccinea)*. White-lined sphinx moth hatchlings tend to prefer spiderling plants to forage on.

TABLE ONE

Nutrients in *Hyles lineata*

total calories (per 100g dry weight)	444k cal
total fat (per 100g dry weight)	16.23 g
total carbohydrates (per 100g dry weight)	20.45 g
fructose	0.8 g
lactose	1.62 g
total protein (per 100g dry weight)	54.07 g
vitamins (mg/g dry weight)	
niacin	11.2 g
riboflavin	1.6 g
minerals (mg/g dry weight)	
calcium	19.95 g
iron	1.094 g
magnesium	15.65 g
zinc	1.17 g

Micro- and Macro- Nutrients in *Hyles lineata*

Photo by Chip Hedgcock

Harvesting white-lined sphinx moth caterpillars.

braided and hung in the sun, or placed on heated stones to dry. They were relished as a food source, which is not difficult to understand; *makkum* was a delicious food, seasonally abundant, protein- and energy-rich, for a people subsisting mainly on wild desert plants. Nutritionally speaking, *Hyles lineata* are exceptional. Not only do the roasted caterpillars contain useful complex carbohydrates that are converted into sugar and absorbed at a slow, healthy rate, they also provide high-quality, complete proteins and fat with a large energy yield. They are a source of calcium, iron, zinc, magnesium, niacin, and riboflavin, too (see Table 1).

The nature of the lipids found in *Hyles lineata* is also impressive. They contain almost as much fat as hamburger meat, but have almost one-third less saturated fat. Monounsaturated fatty acids, of which *makkum* has plenty, do not contribute to increased cholesterol levels. Furthermore, the two polyunsaturated fatty acids that comprise nearly all of *makkum's* polyunsaturates—linoleic and linolenic acids—are essential to proper metabolic regulation in many tissues, and are important hormone precursors. The traditionally prepared caterpillars also provide more energy (in calories), protein, carbohydrate, riboflavin, and niacin than hamburger meat (see Table 2). A pretty convincing argument for entomophagy!

TABLE TWO

Hamburger vs. *Makkum* Caterpillar

Nutrient	Hamburger, pan fried	*Hyles lineata*, dry roasted
total fatty acids (per 100g)	15.73g	11.13g
saturated fatty acids (as % of total FA's)	45.07	32.17
monounsaturated fatty acids (as % of total FA's)	50.60	30.28
polyunsaturated fatty acids (as % of total FA's)	4.32	37.56

Nutritional Comparison per 100g: Hamburger vs. Traditional *Makkum* Caterpillar

ALTERING THE COURSE:

Reconsidering Insects as Human Food

While we don't often speak of edible insects in this country, the ghosts of our past still inhabit the Earth. Grasshoppers still land in haphazard swarms in the Great Salt Lake, but we now deliberately choose to dismiss them as a possible food source. White-lined sphinx moth caterpillars still roam the desert floor, but they are no longer destined for the frying pan. If they are noticed at all, they are likely to be mistaken as a potential garden pest.

Turning this trend around would be an interesting challenge. We could start by learning about and experimenting with traditional wild-insect foods from our own region. By doing this, we would not only seek and value the knowledge that living elders and oral tradition embody, but we would learn about our history and the natural world around us. However, if you choose to begin this exploration, please be cautious. Many insects elicit allergic reactions in humans, and clearly some insects are toxic; some sting or have a painful bite, bad taste, and/or possibly harmful chemical defenses. Use field guides to identify insects before eating them, and always try new dishes in minute quantities so that you can assess reactions and make educated decisions about whether to either eat more or seek medical care. S

Suggested Reading:

Gordon, David George. *The Eat-a-Bug Cookbook: 33 ways to cook grasshoppers, ants, water-bugs, spiders, centipedes, and their kin.* Berkeley, CA: Ten Speed Press, 1998.

Menzel, Peter, and Faith D'Aluisio. *Man Eating Bugs: The Art and Science of Eating Insects.* Berkeley, CA: Ten Speed Press, 2004.

Sutton, Mark Q. *Insects as Food: Aboriginal Entomophagy in the Great Basin.* Menlo Park, CA: Ballena Press, 1988.

Apache cicada (*Diceroprocta apache*)

photo by Margarethe Brummermann

INSECT DELECTABLES

Wild-caught Cicadas

Immature cicadas that live for years underground will emerge as adults, feed, mate, and die in a matter of days. They can be collected as soon as they emerge, and eating newly emerged cicadas apparently eliminates the need to remove wings and legs, since the hardening process is not yet completed. In 1990, there was a huge cicada emergence event in the midwestern United States, and a local writer, Larry Weintraub, researched the edibility of cicadas and encouraged local residents to eat the insects as a way to control their populations.

Weintraub reported that cicadas sautéed with garlic taste like French fries, popcorn, or chicken. Another source suggested dipping cicadas in a batter and then frying them until crispy and golden brown. Roasted cicadas have been described as "meaty tasting and delicious." For a traditional Thai meal, fry and pound wild-caught cicadas (whole, or with heads removed) and then add to mango chili paste.

Chocolate-covered crickets, insect flour, mealworm chocolate chip cookies, and ant-brood tacos are a few enticing recipes included in the "Eating Bugs" website (hosted by the Manataka American Indian Council at *http://www.manataka.org/page160.html).* Many others are available in the archives of the Food Insect Newsletter at *www.food-insects.com* (a website edited by Dr. Gene DeFoliart, Professor Emeritis, University of Wisconsin-Madison). Don't stop here. Find a cookbook (see suggested readings), and go for it!

TIPS FOR SAFELY HARVESTING, PREPARING, AND EATING INSECTS

CAUTION: Please be aware that **many people have allergic reactions to eating insects,** much as they have to seafood. No matter who you are or why you are eating insects, you should inform yourself as much as possible about the insects you are preparing to eat. Remember that there are real dangers associated with uninformed or indiscriminant entomophagy.

Identify your insect first! Become familiar with specific field marks or other physical or behavioral characteristics of the insect you are seeking so that you don't confuse them with similar insects in the field. Also, become familiar with any potential danger the insect may pose to you, and weigh the risks and benefits before harvesting or eating anything.

Familiarize yourself with traditional or other collection techniques and equipment used for harvesting and preparing the particular insect you plan to eat. Use all available resources, including books and locals and/or elders who have eaten insects in the area.

Observe your collection site for any potential toxins or pollutants. If you are collecting from an aquatic habitat find out about the source of the water and what has happened to the water along its route. If you are collecting from the ground, make sure that the soil is not contaminated with waste from nearby construction or industrial projects, by herbicides, fungicides, pesticides, human, or other waste.

Don't over-collect! When you begin collecting, constantly reassess the habitat and the population of insects you are collecting. A good rule of thumb is to leave at least the same number of insects as you take. Overcollecting may jeopardize the survival of the population. If, however, you are trying to remove insects that are pests in a given situation, then collect as many as you possibly can!

Cook the insects, if possible, to deactivate toxic compounds and minimize risk of intestinal parasites and **remove the head, legs, and wings** of particularly chitinous insects such as grasshoppers.

Eat new insects with caution. Once you have prepared your insects for the first time, eat a very small quantity of them and wait for at least 24 hours to make sure they produce no unwanted effects on you.

Above: Yaqui rattles made from silk moth cocoons. Right: Adult cincta silk moth *(Rothschildia cincta)*.

INSECT ART & ARCHITECTURE

Wendy Moore, Ph.D.
Assistant Professor, Insect Systematics,
Department of Entomology, University of Arizona;
Curator, University of Arizona Insect Collection

photos by Wendy Moore, unless otherwise noted.

Sometimes it isn't the insect itself that catches our attention, but rather it's the signs of their presence. Many insects are highly skilled architects that create structures either to protect themselves or to protect their young. For example, praying mantids make elaborate egg cases that house dozens of eggs and developing larvae, and butterflies and moths make chrysalises and cocoons, respectively, in which the caterpillar (the larva) becomes a pupa and the pupa becomes an adult. One of the most characteristic cocoons of the Sonoran Desert Region is that of the silk moths (such as *Rothschildia cincta*). These caterpillars spin a cocoon of silk on desert shrubs, which Native American groups in Arizona and Mexico have used for rattles of various kinds. Another familiar insect structure in the Sonoran Desert Region can be seen on prickly pear cacti (*Opuntia* spp.). Cochineal scales are tiny insects that suck juices from prickly pear pads; however, the animals themselves rarely seen because they secrete a white waxy coating around their bodies to protect themselves from desiccation and predation, sometimes covering the spiny pads with a lacy white coating. When crushed, these insects produce a deep red substance also called cochineal, which is used as a dye by many Native American cultures and is commercially used as a red coloring known as carmine, common in the food industry as well as in cosmetic products.

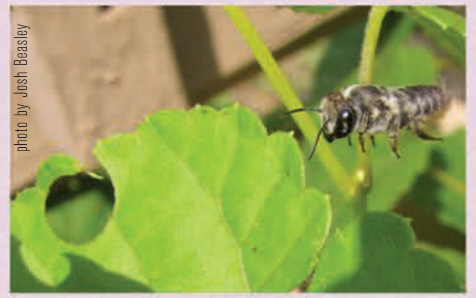

photo by Alex Wild

From left, first photo: Egg cases of mantids are often found attached to tree stems. Second photo: Creosote gall made by the creosote gall midge *(Asphondylia auripila)*. Third photo: Shelter tubes of the long-jawed desert termites *(Gnathamitermes perplexus)* on a barrel cactus. Fourth photo: Cochineal scale made by the scale insect *Dactylopius confusus* on a prickly pear cactus. Fifth photo (top): Leafcutter bee *(Megachile* sp.) in mid flight and leaf with circular hole it cut. Sixth photo (bottom): Desert leafcutter ants *(Acromyrmex versicolor)* carrying their burdens. Cut out photo: Desert leafcutter ant.

The creosote gall is a familiar sight in the Sonoran Desert. Like all galls, these are the products of a collaborative effort between a plant and an animal; the visible structure is an abnormal growth of plant tissue caused by a parasite. In the case of the creosote gall, the structure is caused by the feeding activity of the larva of a small fly known as the creosote gall midge (*Asphondylia auripila*). The burrowing larva induces the creosotebush (*Larrea tridentata*) to form a strange globular growth and the larva develops inside this protective tissue. Leafcutter bees (*Megachile* spp.) cut nearly perfect circles out of broad leaves; the circular leaf pieces are used to create origami-like nest chambers, which they fortify with pollen and in which their young develop.

Many ants are artists. Leafcutter ants (*Acromyrmex* spp.) drop leaves and flowers during their trek from a food source to their nest, thus forming brightly colored trails, not unlike the environmental art of Andy Goldsworthy. Harvester ants (*Pogonomyrmex* spp.) harvest seeds for food. Their nests are most visible in the spring, when wildflowers and grasses cover the ground, because these ants clear vegetation from a circular area around their nests. Scientists have speculated that these symmetrical clearings might reduce the transit time for foraging ants, or they might decrease the risk of exposure to fire or predation, or they might increase nest exposure to solar radiation. So far, the explanation remains elusive.

Many termite species are also artists. They cover their trails and their food with sand particles, creating a visual effect like Christo's modern structural wrappings. The tubes of *Reticulitermes tibialis* and *Gnathamitermes perplexus* termites are commonly seen in the Sonoran Desert. While visually intriguing, the tubes are eminently practical; they provide the termites shelter from the sun and protection from parasites as the termites travel between their food source and their nesting site.

The insect-made structures mentioned here remain after the artist or architect is long gone. Even during the hottest driest times, when insects are inactive or hibernating, these structures remind us that as soon as the rains come and the flowers bloom, our air space will once again be filled with insects flying, buzzing, and vibrating. The signs of their presence are all around us.

Suggested Reading:

Alcock, John. *In a Desert Garden: Love and Death Among the Insects.* Tucson: UA Press, 1999.

photo by Rhonda Spencer

A WEB OF LIFE

Insects, Birds, and Mammals

Karen Krebbs
Conservation Biologist, Arizona-Sonora Desert Museum

Sonoran Desert ecosystems are fragile, and many organisms depend upon one another for their survival and existence. With their great diversity, countless numbers, and the varied functions they serve, insects play a crucial role in the survival of plants and animals here. Their importance in the ecosystems of the Sonoran Desert Region cannot be overstated.

INSECTS & MAMMALS

Insects have been a major food source for mammals for millions of years, as evidenced by the dentitions (the arrangement and kinds of teeth) seen in early mammal fossils. Today, birds are the primary predators of diurnal insects, while bats fill that niche during the evening. Most of the dozen or so bat species in the Sonoran Desert Region dine on yummy juicy insects, while worldwide 70 percent of bat species depend on insects for their survival. Nocturnal moths, numerous aerial insects, beetles, and other ground-dwelling arthropods provide a ready source of food for hungry bats. Some bats are more specialized in their foraging tastes (moth or beetle strategists), while others are generalists who will eat a variety of insects (mosquitoes, flies, gnats, etc.). In fact, many of the insects that bats consume are considered agricultural pests or human pests, and large colonies of bats can ingest tons of insects nightly, helping to keep pest populations in check.

Insectivorous bats use a complicated echolocation system to capture insects (although echolocation is not unique to bats; some species of birds, shrews, whales, dolphins, and porpoises also use sound pulses to locate their prey). With bats, ultrasonic sound pulses are emitted through the mouth and return to the ear as an echo revealing size, shape, speed, texture, and even the direction that the insect is traveling. Bats actually form a sound picture with echolocation; they see with their ears! Once a bat detects the insect, the number of pulses it emits increases from 25 to 250 pulses per second. This is known as a "feeding buzz." During this time, the insect is either captured or the attack is aborted or unsuccessful, and unsuccessful attempts are not uncommon. Many insects—including moths, beetles, crickets, lacewings, katydids, and mantids—have ears that are sensitive to the echolocation calls of bats and can eavesdrop on those that are foraging. Some of these insects can actually jam or block bat echolocation calls, while others dive for the ground or fly away from hunting bats. Some species of moths use noisemakers (clicks) that may startle the bat and end an attack.

photo by Alex Wild

Left page: Coati *(Nasua narica)*. Left: Ox beetle *(Strategus* sp.)

photo by Paul Berquist

Pallid bat (*Antrozous pallidus*).

photo by Alex Wild

Stink bug (*Brochymena* sp.).

photo by Tom Wiewandt

Grasshopper mouse *(Onychomys torridus)* with a cactus longhorn beetle *(Moneilema gigas)*.

Insects that can detect bat hunting calls are 40 percent less likely to be eaten by bats than those that lack that ability. One important advantage that these insects have is that they can detect a bat at about 40 meters, while the bat probably won't detect the insect until it is within 10 meters, thus allowing the insect to escape before the bat detects it. But life continually evolves new strategies, and some species of bats can adjust the frequency of their echolocation call above or below the frequency its insect prey is able to detect. (An interesting wrench in this aerial dogfight is that tiny mites occasionally invade an insect's "ears," decreasing its ability to detect a bat's sound pulses.) Pallid bats *(Antrozous pallidus)* have hearing so sensitive that they can detect the scuffling sounds of insects or scorpions walking on the ground. The pallid bat, and some other bat species as well, use sound to locate prey in much the same way that barn owls listen for their prey. Big brown bats *(Eptesicus fuscus)* will listen to the calls of frogs to locate a wetland habitat with numerous insects. Luckily, the supply of insects is almost inexhaustible.

On the ground, insects are an important dining option in the varied menus of many other mammal species. But the grasshopper mouse *(Onychomys torridus)* is the champion insectivore, with its "wolf-like howl" (high-pitched whistle), hunting "rat packs," and carnivorous diet. To avoid the chemical defenses of many beetle species, this rodent-in-wolf-clothing stuffs the abdomen of the beetle into the earth before consuming it. A striped skunk *(Mephitis mephitis)* will engage in a similar behavior, rolling "stink bugs" in the soil until the little stinkers are safe to eat. Smart guys! Coatis *(Nasua narica)* will dig, probe, and pull up plants in search of nutritious insects that might be feeding on or around the roots. And most shrews *(Notiosorex* spp. and *Sorex* spp.) consume at least 75 percent of their body weight daily in worms, bugs, beetles, and snails to satisfy their voracious appetites and high metabolism.

Other insect-savoring mammals of the Sonoran Desert Region include ringtails *(Bassariscus astutus)*, badgers *(Taxidea taxus)*, coyote *(Canis latrans)*, bobcat *(Lynx rufus)*, foxes *(Vulpes* spp. and *Urocyon* spp.), and the omnivorous black bear *(Ursus americanus)*. Insects also made up part of the diverse diet for the grizzly bear *(Ursus arctos horribilis)* here before this massive mammal was extirpated from Sonora in the 1960s (and from Arizona in the 1930s). Upturned rocks or torn-up logs usually indicated that a grizzly had visited the area in search of ants or fat worms. (And then, as now, bees provided bears with much-coveted honey.) Most predators will take advantage of available insect protein.

INSECTS & BIRDS

Numerous bird species in the Sonoran Desert Region depend on insects either for their entire diet or as one of a variety of food items they consume on a daily basis. Many birds have high metabolisms and require energy-packed foods to fuel their daily routines; thus, birds seek foods that pack a huge nutritional punch, and birds that are normally seed or fruit consumers will switch to an insectivorous diet if that food source is readily available. The time of year can also dictate which foods birds consume. For instance, prior to migrating, birds become eating machines, devouring as much protein or fat as their bodies can tolerate. Many birds will gain more than half of their body weight in fat to fuel their long migrations.

The repertoire of high-speed jumps, turns, twists, and dances performed by insectivorous birds would fit well into any acrobat's circus performance! Using feet, bills, and tongues, they capture insects on the ground, in water, and during aerial pursuits. "Hawking" behavior, where a bird will perch, survey, and dash out for prey only to perch again, is quite common for those bird species that capture aerial insects. Foliage or bark gleaners snatch insects from the surface of leaves or tree trunks. Creepers and nuthatches move up, down, or around the tree, gleaning insects on the bark. Nocturnal birds use their specialized eyes and exceptional hearing to locate their insect meals. You might think birds would pursue larger insects whenever they are available, but larger is not always better when it comes to hunting insects. For example, if capturing a larger insect requires more energy per second of foraging time, then a bird might opt for a smaller insect to satisfy its needs. Less work is better for an energy-conscious bird, and good things do come in small packages.

On the other hand, small may be an issue. Swainson's hawks *(Buteo swainsoni)* generally consume small mammals, birds, reptiles, and insects, but during the nesting season the adult hawks feed their nestlings primarily small mammals and birds. Providing a diet of insects to growing nestlings may require more energy cost in transport for the adult bird, while a diet of small mammals provides the necessary calcium and nutrients for the growth and development of young birds. However, prior to migration, Swainson's hawks derive critical stores of protein and fat from grasshoppers, and agricultural fields serve as gathering places for these raptorsbefore they head south. American kestrels *(Falco sparverius)* appear to be more adapted to capture insects than other prey, and they take full advantage of insect population spikes. They will feed their growing young a combination of grasshoppers, cicadas, lizards, rodents, and small birds. Though known as nectar-lovers, hummingbirds regularly capture insects on the wing or search for them around nectar flowers. Carbohydrates from the nectar provide the quick energy that hummingbirds require for their fast-paced life, while insects provide the needed protein and fat for activities like breeding, nesting, growth, molting, and migration. Insects are important and abundant sources of nutrition for innumerable species.

ON OFFENSE & DEFENSE

Insects are definitely not defenseless against the barrage of predators they face daily. Many insects have evolved to taste bad, smell bad, or have the ability to spray their would-be predators with

photo by Karen Krebbs

Above: Yellow-billed cuckoo *(Coccyzus americanus)*.

Below: The smoke tree sharpshooter *(Homalodisca lacerta)* is a colorful plant-feeding insect about 1cm long.

photo by Alex Wild

photo by Bill Hornbaker

American kestrel *(Falco sparverius)*.

photo by Bill Hornbaker

Ringtail (*Bassariscus astutus*).

photo by Alex Wild

Soldier beetle (*Chauliognathus lecontei*).

photo by Alex Wild

Spotted blister beetle (*Epicauta pardalis*).

distasteful chemicals. Brilliant colors on some insects warn predators that the meal they seek is not worth their trouble—a declaration that prevents it from ending up in a predator's mouth. (It doesn't take long for a bird or mammal to learn what is edible and what is not.) But serving as appetizer or main course isn't the only benefit insects provide for other animals. Some species of ants produce formic acid, a noxious substance that many birds find enticing! Some birds allow ants to crawl over their feathers and some birds actually rub the ants into their feathers to protect themselves from ectoparasites such as feather mites. Ants in short supply? No problem, since there are beetles, termites, snails, or bees that can be substituted for ants for this purpose.

Some insects, of course, chow down on vertebrate hosts. Both birds and mammals will utilize dust to dislodge insect and mite parasites; the dust-choked insects will pack up and move to a cleaner host. Many birds and mammals are the preferred hosts for parasites such as fleas, mites, flies, lice, ticks, larvae, and bedbugs. Some of these parasites specialize on one kind of host, while others will feed on a variety of hosts. Parasites may live in fur or feathers, on wing membranes, or under the skin surface of their hosts. Many of these insects will remain with the host until they die, while others may "jump ship" to a new host. Some nectar-plant mites are transported to other plants in the nostrils of hummingbirds. (It has to be one quick mite to catch a ride, via hummingbird cab, to a new home!) Animals may abandon roosts, nests, and sleep areas if parasites become a nuisance or health hazard. Many birds build new nests rather than remain in old nests that are dirty or infested with parasites. This is the ongoing and exciting warfare of nature.

A biotic community includes all of the organisms living in a given area. The interrelationships and interactions among members of a biological community comprise numerous daily life-and-death encounters, and it is clear that no species is independent of its neighbors. Everything is connected biologically—from the smallest insect to the largest bird and mammal. The insect world provides a massive food supply and much-needed protein and fat for numerous animals. Animals serve as hosts for numerous insects. They can both derive benefits from their association, and life-history strategies and interactions have evolved through these close ecological relationships. Insects, birds, and mammals are essential components of healthy ecosystems throughout the Sonoran Desert Region. S

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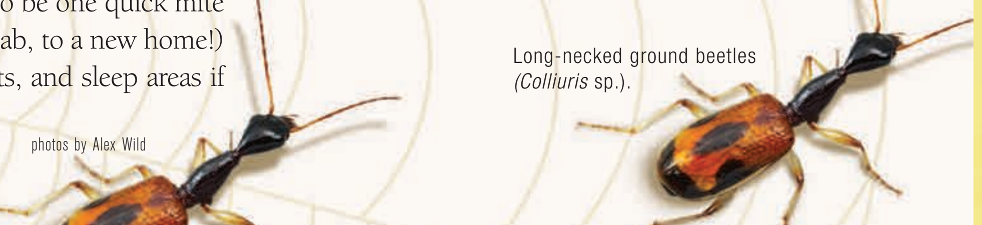
Tuttle, Merlin D. *America's Neighborhood Bats.* Austin: University of Texas Press, 1988.

Wilson, Don E., and Sue Ruff (eds.). *The Smithsonian Book of North American Mammals.* Washington, D.C: Smithsonian Institution Press, 1999.

Johnsgard, Paul A. *The Hummingbirds of North America.* Washington, D.C.: Smithsonian Institution Press, 1983.



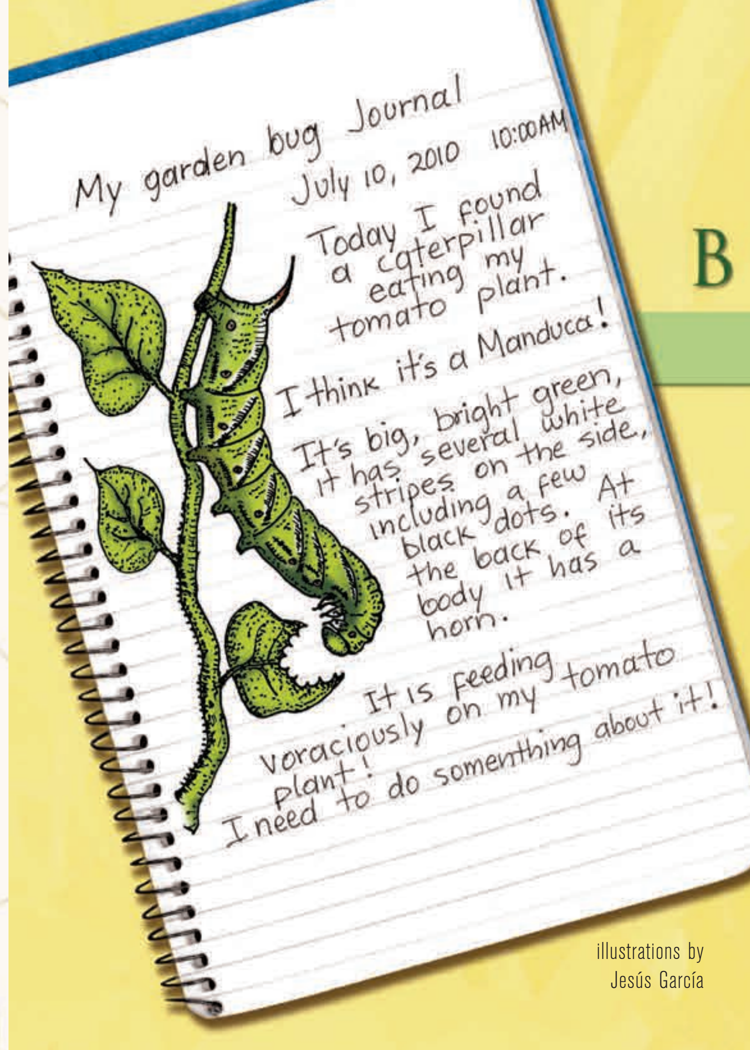
Long-necked ground beetles (*Colliuris* sp.).

photos by Alex Wild

BUG BIOLOGY *in Your Backyard*

Robin Kropp
Education Specialist, Arizona-Sonora Desert Museum

Jesús García
Education Specialist, Arizona-Sonora Desert Museum



illustrations by Jesús García

Whether you are eight or eighty, you'll find that your backyard can be a great place to observe insects and other arthropods. They are an endless source of entertainment and an informative window into the complex, closely knit, and fascinating relationships of nature. We recommend you venture out on a backyard safari.

When you discover a new creepy crawly, watch closely. What does it look like? How many legs, wings, or antennae does it have? Careful observation and a simple field guide can help you determine what kind of arthropod you have found. You can also observe its behaviors. What is the animal doing? What does it eat? Where does it rest, feed, or drink? How does it move? Is it solitary or social (living and working in groups)? Use a hand lens or magnifying glass to observe the creature's features more closely. Keep a journal of your observations. Describe and draw what you have found. With their varied shapes and often striking colors, insects and other arthropods make beautiful subjects for artwork. Include the date so you can track sightings throughout the year.

Careful observation will reveal a world of neighbors you never knew you had. Those hidden from easy view may be enticed to share their secrets in the following ways.

- Drop a few grains of sand or blow into an antlion pit. Watch the antlion larva (doodlebug) try to grab its "prey" with its pinching mandibles or shower it with sand to prevent its escape.
- Put out food to attract insects. Scatter seeds, bits of vegetables or fruits, or small pieces of meat near anthills and see which foods they prefer. Set out a pan with a small amount of honey, molasses, or sugar water, or cut fruit to lure butterflies, moths, and flies.
- Collect mesquite, palo verde, or other bean tree pods that have fallen to the ground. These often contain tiny holes made by bruchid beetles and the wasps that prey upon them. Put the seed pods in sealable plastic bags and watch the hidden insects emerge as the days or weeks pass.
- Use black lights (ultraviolet lights) to lure or

photo by Dr. Richard Vogt

Complete life cycle of tobacco hornworm *(Manduca sexta)*—caterpillar (left), chrysalis (right) and moth—closely related to and often confused with the very similar tomato hornworm *(M. quinquemaculata).* Both hornworm species feed on tomatoes, tobacco, and other plants of the family Solanaceae.

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Tobacco hornworm *(Maduca sexta).*

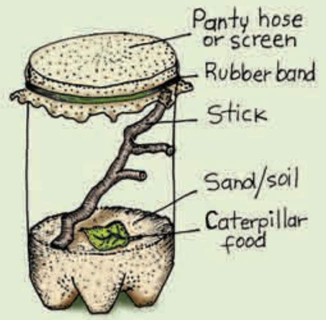
MAKE A BOTTLE HABITAT

If you grow tomatoes, peppers, eggplant, or chiles in a summer garden, you've probably seen large, green, horned caterpillars devouring the leaves of your plants. These larvae are tobacco hornworms *(Manduca sexta)*, and they thrive on plants in the potato or nightshade (Solanaceae) family, like the garden vegetables just mentioned, as well as native plants like sacred datura and desert tobacco. They eat prodigiously, grow quickly, and pupate underground in cocoons, emerging two or three weeks later as large moths called hawk moths or sphinx moths.

You can create a temporary habitat for a Manduca caterpillar to watch it feed, pupate, and become a moth.

You will need:

Clear plastic 2-liter (or ½-gallon) soda bottle
Sandy soil from your yard
Ruler
Small stick (about 6 inches long)
Scissors
Panty hose or porous cloth like tent netting (8" x 8")
Large rubber band
Fresh pieces of the caterpillar's food plants (leaves from a plant in the potato family)



PREPARING THE HABITAT:

Clean the container and remove labels. Cut the top of the bottle off about 4 inches below the lid (see diagram.) (Young children will need help from an adult.) Fill the container about one-quarter full of sandy soil. Place one end of the stick into the soil about an inch deep, and lean the other end against the upper side of the bottle. Set the cloth on top of the opening and secure it with the rubber band.

FINDING A RESIDENT *for your bottle habitat:*

Look for *Manduca* caterpillars on plants in your yard during the summer months. The plants they eat are called their "food plants" or "host plants." The caterpillars grow quickly as they eat. If a human baby were to eat at the same rate as some moth caterpillars, the baby would have to devour over 600,000 pounds of food in its first four weeks of life! When *Manduca* caterpillars get long and plump—about 2 or 3 inches in length—they are about to pupate. This is the time to invite one into your bottle habitat. Remove the cover and put some fresh pieces of a host plant in the bottle. Carefully lift the caterpillar and put it on the plant pieces inside the habitat. Close the bottle with the cloth and rubber band so the caterpillar is safe inside.

Now you get to watch your caterpillar up close. As it eats, it will get all the moisture it needs from the fresh leaf pieces you provide, so you do not need to add water. If the caterpillar runs out of food, put in more pieces of host plant. Clean out its droppings while you have the bottle open. When it is fully grown and ready to pupate, the caterpillar will stop eating and begin to wander around its habitat. It will then burrow into the soil. Don't worry if you don't see it for a time; it may stay in the soil for two or three weeks. When it has pupated, it will climb up from the soil and stand on the stick while its newly formed wings stretch out and become firm. Remember to keep checking the bottle because you will want to release the moth soon after it emerges from the soil.

reveal otherwise unseen nocturnal arthropods. Hang a white sheet in your backyard at night with a black light (or even a plain "white" light) in front of it to attract winged or crawling critters. Or shine a black light on the ground. You may be surprised by the number of blue-green fluorescent scorpions that call your yard home!

HABITATS

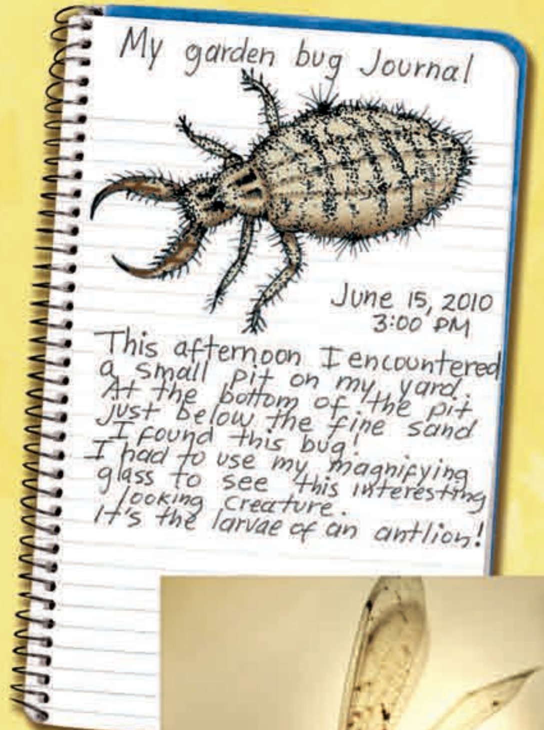
The more you learn about insects and other arthropods, the more you realize their benefits as pollinators, pest controllers, and food for other animals. You can bring these benefits to your backyard by improving arthropod habitat through landscaping with native plants and features that provide food, shelter, and moisture.

You may also want to create miniature, temporary habitats where you can house arthropods and watch them closely for a few days before you release them back into your backyard. One easy way is to make a bottle habitat.

You can follow the same process we've outlined for the tobacco horn worms with other caterpillars. A similar species is the yellow-and-black horned sphinx moth caterpillar *(Hyles lineata)*. These pupate in the same way but require wild host plants. If you live near relatively undisturbed desert, you may find many of these during the summer rainy season.

Other arthropods you may want to observe in a bottle habitat include praying mantises, spiders, scorpions, beetles, and ladybird beetles ("ladybugs"). Look on the internet or in books to see what foods and other habitat elements they require, and recreate that in your bottle habitat. For more bottle biology ideas, visit the website: *www.bottlebiology.org/basics/index.html#cuttingbottles.* For more on tobacco hornworms, check out the *http://insected.arizona.edu/manduca/default.html* website.

Bottle habitats are fun for observation, but they are only temporary. Always remember to release your arthropods back into the wild, so they can continue to provide ecological benefits to your backyard and beyond. S



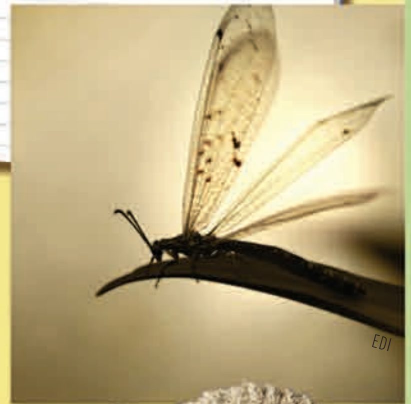


photo by Scott Robinson

above: Antlion adult.
cutout: Antlion larva.

Suggested Reading:

Friederici, Peter. *Strangers in Our Midst: The Startling World of Sonoran Desert Arthropods.* Tucson, AZ: Treasure Chest Books, 1997.

Ingram, Mrill, Stephen Buchmann, and Gary Nabhan. *Gardening for Pollinators in the Desert Southwest*, a pamphlet. Tucson, AZ: Arizona-Sonora Desert Museum Press in cooperation with the Arizona Native Plant Society, 1998.

CREATING HABITAT FOR Arthropods

When unaware of the ecological roles insects play in pollination and in the food web, many people view insects and other arthropods as pests. Once aware of their invaluable contributions, however, we are more apt to welcome rather than discourage their residence in our yards, which can be a source of food, moisture, and shelter for these beneficial and entertaining animals. Here are some ways to create habitat for arthropods.

Go Native: Native plants provide resident creatures with the foods to which they are best adapted. A variety of flowering plants will meet a diversity of wildlife needs while providing a colorful landscape that changes through the seasons. As a bonus, native plants require little water or labor to maintain.

Just a Little Water: Once established, most plants native to the Sonoran Desert don't require supplemental irrigation, but resident animals do appreciate a little water. A landscape feature, a slow-dripping tap, or even a patch of damp earth, can provide water, and/or salts and other minerals for animals like butterflies and bees.

Free Housing: A complete arthropod habitat will need safe roosting or nesting sites. The best way to provide them is to resist being too tidy. Don't want to prune that dead branch just yet? Good idea. A few dead tree limbs and broken twigs offer important real estate for wood-boring bees and beetles.

Poison-Free Living: Minimize the use of pesticides and other toxic chemicals in your landscape. Use alternative forms of insect control like soapy water or the many biological control agents (like ladybird beetles) available on the market today. Or try planting marigolds, chrysanthemums, or basil, which work like natural insecticides around your garden.

Sit back and enjoy the show as plants and creatures interact in the home-sweet-home of your shared backyard.


1 — photo by Bob Behrstock

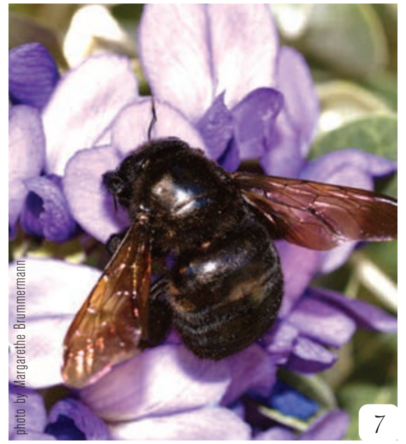

2 — photo by Katja Schulz

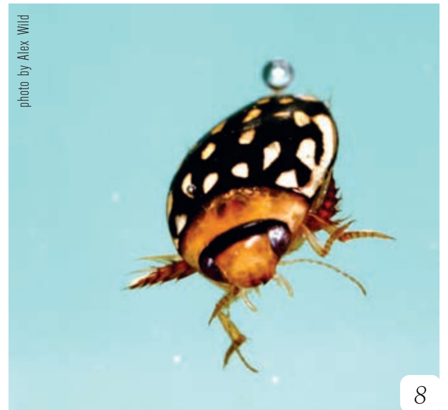

3 — photo by Jillian Cowles

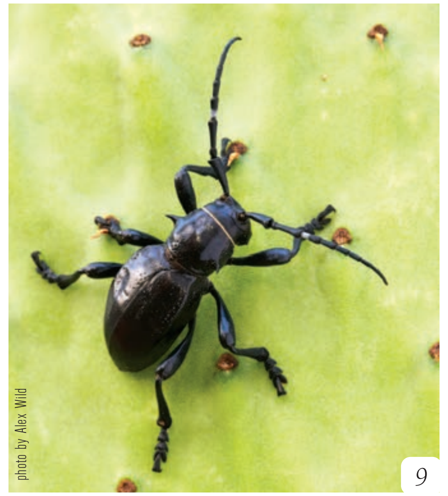

4 — photo by Doris Evans


5 — photo by Jillian Cowles


6 — photo by Doris Evans


7 — photo by Margarethe Brummermann


8 — photo by Alex Wild


9 — photo by Alex Wild


10 — photo by Alex Yelich

1. Greater angle-wing katydid *(Microcentrum rhombifolium)*. This is a widespread and common katydid found throughout the eastern half of the United States and in riparian areas of the Southwest, where it feeds on the foliage of deciduous trees and shrubs.

2. Cactus fly *(Odontoloxozus longicornis)*. Often seen in the Sonoran Desert, this odd-looking fly is a member of the family Neriidae, commonly known as stilt-legged flies. Males and females mate on rotting cactus flesh, where the females deposit their eggs and the larvae develop. These curious (and harmless) flies often visit outdoor diners in the evening.

3. Velvet ant *(Dasymutilla asterius)*. Females of this species are wingless and can inflict a painful sting, whereas males are winged but stingless. Their larvae are parasitic on several species of bees and wasps.

4. Seed beetles (Bruchidae). These beetles infest seeds of various plant species, where the larvae feed until they emerge as adults. In the Sonoran Desert many species of seed beetles develop in mesquite bean pods, where they leave tiny exit holes after they emerge as adults.

5. Iron-cross blister beetle *(Tegrodera aloga)*. Adult iron-cross blister beetles can be quite abundant when they emerge in the spring, feeding on the blossoms and foliage of various herbaceous plants. Their larvae are parasitic on the larvae of various soil-nesting bees.

6. Hover fly (Syrphidae). These beautiful flies are a pleasure to watch. Primarily nectar and pollen feeders, they are best known for their ability to hover in one place for an extended period of time.

7. Carpenter bee *(Xylocopa californica)*. Large adult carpenter bees emerge in spring and feed on pollen and nectar. Females chew into dead wood to create large tunnels with up to eight chambers in which eggs are laid. Each chamber is fortified with pollen and regurgitated nectar, providing food for the developing larvae.

8. Predaceous diving beetle *(Laccophilus pictus)*. These beetles are found in standing water and slow streams. Adults and larvae are both predaceous, feeding on other aquatic insects, tadpoles, and small fish.

9. Cactus longhorn beetle *(Moneilema gigas)*. This longhorn beetle (family Cerambycidae) is common throughout the Desert Southwest wherever prickly pear and cholla cacti grow. Its larvae bore into the roots and stems, while adults, which emerge in the summer rainy season, feed on the tops of the cactus stems.

10. A "flower moth" caterpillar *(Schinia* sp.) wonderfully camouflaged on a desert marigold *(Baileya* sp.). The larvae of "flower moths" feed on flower buds, blooms, and seedpods of their host plants.

11. Snail-eating beetle *(Scaphinotus petersi)*. This attractive ground beetle has evolved specialized elongate mouthparts for attacking snails in their shells. Whereas adults are specialized for eating snails, the larvae are predatory generalists, feeding on various small insects.

12. Bark-gnawing beetle *(Temnoscheila chlorodia)*. These brilliant metallic green beetles can be found on and under the bark of many types of trees, where they feed on the larvae of various bark-boring insects.

13. The Terloo sphinx moth *(Proserpinus terlooii)*. This is one of the smallest sphinx moths in our region with a wingspan that is less than two inches. This beautiful olive green species is known only from southern Arizona and Sonora, Mexico.

14. Chrysalis of the pipevine swallowtail butterfly *(Battus philenor)*. The pipevine swallowtail is also common throughout the southern and eastern United States. Adults are large and black with metallic blue-green hind wings and red spots on the underside. The caterpillars feed on pipevines *(Aristolochia* spp.) and various herbaceous plants.

15. Painted grasshopper *(Dactylotum bicolor)*. This striking grasshopper is found throughout the western Great Plains and Desert Southwest into Mexico. The nymphs hatch in the spring and feed on grasses until reaching adulthood in late summer.

16. Red and white wave moth *(Idaea basinta)*. Common from Arizona to western Texas, these attractive little moths fly to lights at night like many other night-flying insects. Their caterpillars, like others in the family Geometridae, are known as "inchworms" or "loopers" due to their unique locomotion.

17. Arizona tortoise beetle *(Physonota arizonae)*. Adults and larvae of this tortoise beetle feed on the foliage of herbaceous plants. Extended body margins appear as clear flaps completely covering the legs, creating the appearance of a turtle-like shell.

18. Leaf beetle *(Zygogramma* sp.). The leaf beetles of this genus feed primarily on plants in the sunflower and daisy families. Like tortoise beetles, both adults and larvae of these leaf beetles feed on foliage.

19 Harvester ants *(Pogonomyrmex rugosus)*. Harvester ants build large, complex underground nests where they store seeds for food. They possess one of the most toxic venoms of any insect, which makes their bite very painful.

20. Caterpillar of Cecrops-eyed silkmoth *(Automeris cecrops)*. This silkmoth caterpillar has branching spines that inflict a painful bee-like sting. Adults of this attractive moth emerge during the summer rainy season in southeastern and central Arizona. They have large eyespots on the hind wings that startle would-be predators.


11 — photo by Alex Wild


12 — photo by Alex Wild


13 — photo by Alex Yelich


14 — photo by Carl Olson


15 — photo by Michael C. Thomas


16 — photo by Alex Yelich


17 — photo by Alex Yelich


18 — photo by Alex Wild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20 — photo by Michael C. Thomas

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