WINGS

ESSAYS ON INVERTEBRATE CONSERVATION

THE XERCES SOCIETY SPRING 2014

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This issue of *Wings* sheds light on two very different and largely understudied groups of invertebrates. The first article looks at the impacts of oil spills on marine species. The other two essays focus on arachnids; one introduces us to a citizen-science project studying spiders in Colorado, and one to the fascinating order of camel spiders.

The Changing Landscape of Conservation

Scott Hoffman Black

I have worked on the conservation of rare and declining animals for more than twenty-five years. For invertebrates this has typically meant addressing the conservation needs of animals living in a small number of easily identified sites. This type of conservation work is often straightforward: You prioritize specific issues that help the species thrive on the habitat that remains and, where feasible, work to expand habitat. We manage livestock to prevent overgrazing of meadows that support rare butterflies, restore sand dunes degraded by human activities for tiger beetles, or ensure that enough water flows through streams harboring rare stoneflies. Work such as this is vital to ensure the survival of endangered species and will continue to be a focus of the Xerces Society.

Unfortunately, the conservation landscape is changing, and over the last few years we have started to see declines in widespread and common species. The rusty patched bumble bee used to be common from the upper Midwest

It is becoming increasingly apparent that even species that were once common or widespread are disappearing from our landscapes. Rusty patched bumble bee (*Bombus affinis*), photographed on catnip (*Nepeta*) by Christy Stewart.

to the Northeastern seaboard. It is now only found at a few dozen sites across its range and warrants endangered species protection. An analysis of the status of all North American bumble bee species, undertaken by the Xerces Society in conjunction with the continent's leading bumble bee scientists, shows that approximately one-third of all species are of serious conservation concern. Many of these were the ones you would have seen in your yard.

Widespread butterfly species are also becoming less common. Monarchs have declined from perhaps as many as half a billion butterflies in the mid-1990s to only 33 million today. That may seem like a large number, but it represents a drop of more than 90 percent. This could have serious ramifications for monarch migration, and in the coming years monarchs may be missing from many areas of North America where they were formerly common. The loss of monarchs has been tracked thanks to a loyal band of enthusiasts; other common butterflies have also suffered marked declines but these have generally occurred with little public awareness.

A few years ago, I gave a keynote talk on the status of North American butterflies at the International Butterfly Conservation Symposium in Reading, England. In preparation I compiled information about the continent's butterflies. The data from NatureServe, an organization that produces scientific assessments of biodiversity, suggested that more than 17 percent of butterfly

With a dedicated following of gardeners and advocates, the monarch is a flagship species for conservation. Steep declines in the butterfly's population mean that it may be missing from gardens in coming years. Monarch (*Danaus plexippus*) nectaring on blazing star (*Liatris*), photographed by Bryan E. Reynolds.

species were at risk of extinction. But this data has a limitation; it shows only whether a species is at risk of extinction, not whether it is in decline.

I next asked a series of questions of many of my colleagues who have decades of experience in studying and conserving butterflies. I was amazed that most of the responses to the last question—what is the most important take-home message about butterfly conservation in North America?—were a variation on the same answer: Common butterflies seem to be declining across broad landscapes.

Here are three comments that resonated most deeply. Dr. Jaret Daniels, of the University of Florida, said, "what should be most alarming to all of us is that this downward trend has now spilled over to include many previously more wide-ranging and common butterflies." Dr. John Shuey, chair of the Lepidopterists' Society's conservation committee, noted that "many species we once took for granted are in serious trouble." This was underscored by Dr. Art Shapiro, of the University of California at Davis, who has been monitoring butterflies on the same sites in California for nearly forty years: "My research group can say that lowland butterfly faunas, including 'weedy' species, are declining precipitously."

Why is this occurring? We don't know for sure, although there are several likely contributing factors. Habitat loss due to urban development and large-scale agriculture are key concerns. Farms now cover vast areas and many grow genetically modified crops that allow herbicides to be used on a much larger scale on and around them. These "Roundup-ready" crops have become a major cause of milkweed loss throughout the Midwest and are thought to be a principal reason for monarch decline. Millions of acres of farms and urban land are also treated with insecticides. Neonicotinoids, the most commonly used insecticides in the world, have been in the spotlight because the science suggests that they are having a profound impact on both terrestrial and aquatic insects and other invertebrates. Diseases spread from managed bumble bees may be playing a major role in the broad decline in native bumble bees. The last significant factor is climate change, more accurately referred to as climate destabilization. A year of drought is broken by intense rainstorms, winters seem colder and blizzards more frequent, the hurricane season sends powerful storms further north: animals have a lot to contend with.

So how do we address large-scale, widespread declines of species we formally took for granted? Putting fences around habitats will not work. Large areas of high-quality, insecticide-free habitats will be needed and these habitats must be connected wherever possible. This is not an effort that is restricted to distant wilderness, but a cause in which everyone can take part. Homeowners and farmers can plant native flowers and work to limit the impact of insecticides; land managers can provide resilient habitat for a variety of species; and all of us can vote with our pocketbooks by buying sustainable, organic, and GMO-free products.

Aldo Leopold wrote in *A Sand County Almanac*, "One of the penalties of an ecological education is that one lives alone in a world of wounds." It is time to heal as many wounds as possible.

Oil Spills and Marine Invertebrates

Scott Hoffman Black, Michele Blackburn, Celeste Mazzacano, and Candace Fallon

The names *Exxon Valdez* and *Deepwater Horizon* are seared into our collective memory as environmental disasters without parallel. In 1989 the *Exxon Valdez* smashed into rocks in Alaska's Prince William Sound and spilled at least 11 million U.S. gallons (42 million liters) of oil—some calculations estimate that the volume was twice that much—which ultimately spread across 400 miles (650 kilometers) of shoreline. As the oil fanned out, it coated rock surfaces and penetrated sediments, causing widespread mortality and morbidity among the coastal and intertidal mussels, echinoderms, amphipods, and crabs that made their homes in Prince William Sound. Exposure persisted for as much as twenty years at those sites where oil remained trapped in sediment.

This was the largest single oil spill in U.S. waters—until April 2010, when an explosion occurred on the *Deepwater Horizon* drilling platform in the Gulf of Mexico, killing eleven crew members and injuring sixteen. Two days after the initial disaster, the stricken platform buckled and collapsed into the Gulf. The blowout, which occurred at a depth of five thousand feet, left a ruptured wellhead spewing crude oil into the waters of the Gulf for nearly three months. A vast plume of oil—estimated to contain at least 193 million gallons (730 million liters) of oil—was dispersed by wind and currents; this oil impacted almost every habitat in the northern Gulf, including the deep-sea floor, and moved through the water to coastal wetlands, estuaries, beaches, and mangrove stands.

These may be the events people remember best, but they are by no means the only significant oil spills in the last half century. In 1969, the barge *Florida* sank in Buzzards Bay, Massachusetts, spilling 185,000 gallons (700,000 liters) of fuel oil. The *Tsesis* oil tanker spilled about 252,000 gallons (955,000 liters) of fuel oil along the coast of Sweden in the Baltic Sea in October 1977. The *Ixtoc I* platform blowout in 1979 released an estimated 140 million gallons (530 million liters) of oil into the Bay of Campeche in the southern Gulf of Mexico. The *North Cape* barge struck ground during a storm off the coast of Rhode Island in January 1996, spilling an estimated 828,000 gallons (3.1 million liters) of fuel oil into Block Island Sound.

More than 200 million gallons (757 million liters) of oil are spilled into the ocean by humans every year. Most of this oil is spilled during small events and routine activities, including the discharge of ballast water from oil tankers, waste from oil refineries, and such on-land sources as effluent from sewage treatment plants and runoff from roads and parking lots.

In the aftermath of an oil spill, the news broadcasts often show images of dead mammals or of birds covered with

oil, but we almost never hear about the impact these spills have on invertebrates. There are some valid reasons for this lack of coverage: we know much less about the invertebrates that inhabit our oceans than we do about the mammals and birds, and they often live near the ocean bottom or are small animals that float in the water column, making them difficult to notice. It makes sense that we track the larger, easy-to-see animals following an oil spill, but research suggests that such spills in our oceans can have a long-lasting impact on invertebrates, which in turn has the effect of disrupting the entire food web.

Marine invertebrates are key components of all marine ecosystems, and they play critical roles in essential ecological processes. Despite their importance, the vast majority of marine invertebrates are poorly known. According to *Spineless: Status and Trends of the World's Invertebrates*, a report produced by the International Union for Conservation of Nature (IUCN) and the Zoological Society of London, there are between 200,000 and 230,000 described marine species, with more than two million estimated to exist in total. Invertebrates make up more than 95 percent of all marine animal species. Living in a wide range of habitats, from tropical waters to the polar seas and from the surface to the deep ocean, marine invertebrates display a vast diversity of forms, sizes,

More than 200 million gallons of oil are spilled into the oceans each year. Oil-coated shores are an obvious result, but most of the oil is dispersed into the marine ecosystem, where it can have decades-long impacts. Photograph © Danny Hooks, iStockphoto.

The Gulf of Mexico is one of the planet's most biodiverse water bodies. Coral reefs provide habitat for many species, including several of economic importance. Photograph courtesy NOAA Photo Library.

and adaptations. They range in size from microscopic zooplankton to the giant squid, reported to be up to twenty yards (eighteen meters) in length.

Widespread threats from climate change, exploitation, habitat degradation, and other natural and anthropogenic sources are increasingly putting marine invertebrates at risk, but the full extent of these impacts is largely unknown. There are more than thirteen hundred species of marine invertebrates included on the IUCN Red List of Threatened Species. Of the assessed invertebrates, about a quarter are threatened with extinction, while for another quarter we lack adequate information to even guess at their risk of extinction.

What we do know is that these animals are essential to the vitality of our oceans. They are an integral part of food webs, comprising part or all of the diets of many fish, birds, and mammals. Zooplankton (tiny crustaceans, mollusks, and jellyfish, and the embryos and larvae of other invertebrates), which are the dominant component of pelagic (open water) communities, form an important link in the marine food web, transferring energy captured by microscopic phytoplankton (single-celled photosynthetic organisms) to higher-order consumers, including fish, whales, and birds. The invertebrates inhabiting the benthic zone (the sea floor) are an important food source for other invertebrates such as lobsters, crabs, snails, sea stars, and octopuses, as well as birds, fish, and marine mammals. Marine invertebrates are also key prey items for

sensitive species such as the federally endangered loggerhead sea turtle (*Caretta caretta*), blue whale (*Balaenoptera musculus*), and right whale (*Eubalaena* spp.), and the rufa red knot (*Calidris canutus rufa*), a shorebird that has been proposed for threatened status.

Marine invertebrates also have great commercial importance, in the harvesting of lobster, crab, sea scallops, shrimp, squid, oysters, and sea cucumbers. Global production of wild shrimp totals 3.75 million tons (3.4 million metric tons) a year; the shrimp trade, valued at $10 billion, is the largest commercial fishery in the world. U.S. oyster harvests yielded 28.5 million pounds (13 million kilograms) valued at $132 million in 2011, and in 2010 the commercial catch of blue crab exceeded 222 million pounds (100 million kilograms). U.S. waters also support the world's largest wild sea scallop fishery, which yielded 57 million pounds (26 million kilograms) of meat worth some $450 million in 2010.

The commercial value of marine invertebrates is not limited to their consumption as food. Many of them synthesize complex chemical compounds for defense, communication, competition, and prey capture, and thus have substantial economic importance as a source of unique chemical compounds. Some thirty thousand natural products have been isolated from marine organisms, the majority of which are from invertebrates. These products are used in a variety of pharmaceuticals, cosmetics, nutritional supplements, and pigments.

Coral reefs have significant tourism value as sites for such activities as scuba diving, snorkeling, and recreational

The feathery "branches" of the marine polychaete Christmas tree worm (*Spirobranchus giganteus*) have a dual purpose, collecting food and acting as respiratory organs. The remainder of the worm lives in a hole bored into the substrate. Photograph courtesy NOAA Photo Library.

fishing. In the Florida Keys, reef-based tourism generates more than $1.2 billion annually; dive tourism in the Caribbean generated $2 billion in 2000; and reefs in tourist areas of Indonesia have been valued at $2.6 million per square mile ($1 million per square kilometer).

The habitats created by marine invertebrates are ecologically and commercially important in a variety of ways. Coral reefs support nine million different species—30 percent of the oceans' total—and catches from reef regions account for 10 percent of fish consumed by humans. Coral reefs also form living breakwaters that dissipate wave energy, prevent erosion, and increase sedimentation rates near shorelines. Similarly, the dense beds formed by oysters not only create habitats that support a diverse, abundant fauna in intertidal areas, but also stabilize sediment and protect shorelines from erosion. An acre of oyster-bed habitat can provide coastal protection valued at $212,000 per year ($86,000 per year for a hectare).

Invertebrates are already threatened by pollution, habitat degradation, and global climate change, and oil spills represent an additional persistent threat. We know that oil spills are having a negative impact on invertebrates even though this effect has not received widespread publicity. Oil spilled by the barge *Florida* in 1969 moved into marshes where it killed crabs, amphipods, worms, mollusks, and other benthic invertebrates, and continued causing harm for more than thirty years. Six years after the tanker *Arrow* ran aground off the coast of Nova Scotia in 1970, spilling 294,000 gallons (1.1 million liters) of oil into Chedabucto Bay, soft-shelled clams were still being exposed to oil trapped in sediments, and their populations were consistently lower at oiled locations; impacts to benthic invertebrates were documented for

Oil compounds accumulate in invertebrates, and the contamination is passed up through the food web. Photograph from Wikimedia Commons/4028mdk09.

Gorgonian soft corals are a highly diverse and important part of deep-water communities. Photograph of *Iridigorgia pourtalesii* courtesy NOAA Photo Library (Aquapix and Expedition to the Deep Slope 2007).

twenty years. When the *Amoco Cadiz* ran aground off the northwest coast of France in March 1978, spilling about 64 million gallons (242 million liters) of oil into coastal waters, high mortality of zooplankton was reported and ampeliscid amphipods were completely absent from sites where they had been the dominant population; it took eleven years for amphipods to recolonize impacted areas and reach pre-spill densities. Following the *Ixtoc I* spill, zooplankton suffered massive population decreases for three years. Soon after the *North Cape* grounded on the beaches of Rhode Island in 1996, spilling more than eight hundred thousand gallons (three million liters) of oil, nearly three million dead lobsters washed ashore.

Four years after the *Deepwater Horizon* spill we still do not know what its full impact will be, but the effects on marine invertebrates were immediate and acute. Deepwater corals exposed to the oil plume were found dead or dying, and mussels and snails on shorelines suffocated after being coated with oil. Zooplankton in the water column were exposed to oil at levels known to cause mortality, and commercial fishing for crabs, shrimp, and oysters was suspended because of contamination. The season in which the *Deepwater Horizon* spill occurred may have increased the severity of its impacts, as the disaster corresponded with the spawning period of many corals, crabs, shrimp, and oysters, and the early life stages of these animals are especially sensitive to oil.

Given the diverse key roles that marine invertebrates play in deep-sea and coastal habitats, potential ecosystem service losses related to oil spills are of enormous concern. The impacts of the *Deepwater Horizon* spill continue to be seen today, as invertebrates still exhibit impaired disease resistance, decreased growth and reproduction, and slow population recovery. Oil remains trapped in sediments of both coastal marshes and

Gastropods such as the flat periwinkle (*Littorina obtusata*) are common in intertidal environments, and thus vulnerable to oil contamination of shorelines. Photograph by Sandy Rae/Flickr.

deepwater habitats, which may extend the impacts on invertebrates by decades.

Oil spills have affected—and will continue to affect—invertebrates and their habitats across the globe. There is no question that spilled oil is highly toxic to marine invertebrates and that this toxicity is long-lasting, but, because of the extreme diversity of marine invertebrates and the relative lack of research, we still know little about the ultimate ecosystem-wide impacts of these events. More—and more precise—baseline data are needed on existing populations of ocean invertebrates, so that we can better understand how these important animals are being affected—not only by oil spills but also by cumulative additional impacts such as other types of pollution, habitat degradation, over-fishing, and climate change. A tremendous amount of scientific expertise is available globally to conduct these baseline studies—for example, IUCN specialist groups are working specifically to determine the extinction risk of many marine invertebrates—but funding sources are lacking.

In addition to expanding our baseline knowledge of invertebrates in coastal, coral-reef, open-water, and deep-sea habitats, more research must be focused specifically on marine invertebrates in the aftermath of oil spills, both to monitor immediate and long-term impacts, and to increase our understanding of the process of recovery.

Despite regulations intended to prevent such events, spills occur when oil is transported, as well as during exploration and drilling activities. No number of precautionary measures can guarantee that spills will never happen. Thus, if we are to protect marine wildlife, we must reduce our consumption of oil while simultaneously following best practices to reduce the possibility and impact of oil spills. This includes developing our understanding of where it is relatively safe to drill, as well as of technologies and practices that can be used to stop or minimize spills. Through conservation of our natural resources, cultivation of a thoughtful approach to where we drill, and the development of better technology, we can ensure that the important animals that form the base of the food chain are protected.

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The Colorado Spider Survey

Paula E. Cushing

Each year, natural areas in the American Intermountain West are profoundly affected by population growth and by the expanding development that such growth brings with it. The resulting habitat degradation acts to drive wildlife out of formerly pristine areas. Those affected by these changes include not only the mule deer, bighorn sheep, bears, elk, coyotes, and other large animals for which this area of the country is so well known, but also smaller and often overlooked animals such as spiders and insects.

Researchers have documented the distribution and species diversity of several groups of insects in the western states, including ants, grasshoppers, and butterflies, but such information about other arthropods is lacking. One group that is particularly understudied is the order Araneae, the spiders. Little is known about spiders of the western United States, making it difficult to know how habitat changes are affecting particular species.

Although spiders are often regarded with consternation, they play an important role in the environment. As predators they consume countless other arthropods, reducing pest populations; indeed, some are now recognized for their valuable contribution in managing crop pests. Spiders are also often prey themselves, and are, for example, a significant component of the diet of

Spiders can be found everywhere from deserts to flower gardens, but are largely understudied. In Colorado, a statewide survey is helping to expand our knowledge of these animals. *Misumena vatia*, photographed by Bryan E. Reynolds.

The Colorado Spider Survey is documenting the distribution and abundance of Colorado's spiders, even uncommon ones such as *Araneus illaudatus*. Photograph by Bryan E. Reynolds.

many birds, including—somewhat unexpectedly—hummingbirds.

In 1999, I initiated a regional citizen-science project to rectify the lack of knowledge about the biodiversity of spiders in the Intermountain West. The Colorado Spider Survey (CSS) was modeled after the Ohio Spider Survey founded by Dr. Richard Bradley, author of the beautifully illustrated field guide *Common Spiders of North America*. Both surveys are designed to document regional diversity of this understudied group of arthropods and to engage interested members of the public in this enterprise.

"Citizen science" is a term for efforts in which volunteer members of the public, most of whom have no formal training in science, become actively involved in research. CSS participants identify spiders and record where they are found. Cumulatively, these data describe both the diversity of spiders in Colorado and their geographic distribution, creating a baseline for future studies to demonstrate whether and how these species distributions change.

People get involved in the CSS by accessing the project's website, attending a free training workshop, or taking my spider-biology class offered through the Denver Museum of Nature & Science. Since 1999 nearly eight hundred people—adults, families with bug-crazy kids, park personnel, teachers—have been trained. Over the years, almost 20

percent of participants have remained active with the survey for some period of time past the initial training event, and even those who do not remain active leave the training with a better understanding of and appreciation for these animals. In fact, one particularly important aspect of the survey is that those who participate become advocates for spiders and spokespersons for the value of understanding the biology of overlooked groups of fauna and the importance of preserving the Earth's biodiversity.

Some of those who remain active members of the CSS are solely field collectors, rarely making an appearance except when they come to the museum to drop off specimens. Other participants become outreach ambassadors, taking the information they have learned through the CSS and using it for public programs in their schools, parks, or clubs; several of the teachers, for example, have involved their students in the project. A large number become active as museum volunteers in the arachnology collection—curating incoming specimens, identifying them, and recording collection data, which are compiled and published in an online database, Symbiota, a project of the Southwest Collections of Arthropods Network. A few CSS participants have pursued graduate degrees in arachnology-related fields or have initiated their own research projects, and several have presented posters or papers at conferences on their own CSS-related work.

From the outset of the project some fifteen years ago, it has been important to help the participants stay connected and engaged over the long term, and one valuable tool has been our "arachnophile" distribution list. Twice a year, we send out a project newsletter, the *Beat Sheet*, which includes updates about the project; notices about upcoming classes, workshops, and lectures; announcements for paid and volunteer po-

A burrowing wolf spider (*Hogna antelucana*) watches from its lair. Wolf spiders have excellent vision for spotting prey and long legs with which to chase it down. Photograph by Bryan E. Reynolds.

The black and yellow garden spider (*Argiope aurantia*), as its name implies, commonly weaves its web between garden plants. Photograph by Bryan E. Reynolds.

sitions; participant news (adventures in the field, arachnid-related natural history observations, and other tidbits); and a section on "arachnids in the news." Occasionally, participants who have been inactive for several years suddenly get back in contact and start sending in specimens again, almost certainly inspired by receiving the latest *Beat Sheet*.

When I began my job at the Denver Museum of Nature & Science in 1998, the museum had no arachnid collection. We now have nearly fifty thousand vials containing preserved arachnid specimens; of these, thirty thousand have been identified and entered into the Symbiota database, with the rest of them in the queue to be identified. Incoming and outgoing loan activity (shipping specimens to and from other researchers around the world) has increased every year.

The CSS has documented forty-one families of spiders, representing more than 650 species in the western United States; among these is a new family record (Zodariidae) not previously known in the region. The survey's work has resulted in nineteen scientific publications and fifteen presentations at scientific conferences, with seven of these by CSS participants.

In addition to serving as a means for gathering critical information about the ecology and distribution of this understudied group of animals, the CSS has become a highly effective model for educating members of the public about the importance of biodiversity by involving them in the scientific process. We are creating an army of people who are informed and excited about arthropods, and who are serving as advocates within their own communities for understanding and preserving our planet's rich and diverse array of wildlife.

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For more information or to join the Colorado Spider Survey, please visit http://spiders.dmns.org/. The Symbiota database can be accessed at http://symbiota4.acis.ufl.edu/scan/portal/.

Hairy, Scary, *Haarskeeders*

Paula E. Cushing, Jack O. Brookhart, and Jen Rowsell

Military personnel returning from Iraq or Afghanistan often report being charged during the day by bizarre arachnids called camel spiders. Most camel spiders are nocturnal, and it is likely that in most instances the individuals in question had been displaced from their daytime hiding places and were not pursuing the frightened soldiers; in all probability, they were merely trying to remain in their shadows and thus stay out of the direct sun. In doing so, the camel spiders were living up to the name of their order, Solifugae, Latin for "fleeing from the sun." The order includes twelve families, 141 genera, and approximately eleven hundred described species, with more species being discovered every year.

The oldest fossil solifuge is from the Upper Carboniferous (Pennsylvanian) geologic period, approximately three hundred million years ago. These arachnids are notable for their massively powerful segmented jaws, voracious appetite, feisty temperament, and tremendous speed. They are important predators in harsh desert habitats throughout the world, preying upon any invertebrate large enough to provide sustenance or any vertebrate small enough to catch and subdue. And they themselves serve as food for lizards, scorpions, and other desert inhabitants.

The body of a solifuge is covered with long hairs. These hairs are sense organs, capable of detecting the tiniest changes in temperature, humidity, or air movement. Photographed in South Africa by Piotr Naskrecki.

Since they are neither camels nor spiders, no one really knows how solifuges got the common name "camel spider," but myths abound regarding these pugnacious predators, often relating to one of their many vernacular names. In some parts of the world they are called "wind scorpions," because of their speed. In South Africa, camel spiders are known in Afrikaans as *vetvreters* (fat eaters), or as *haarskeeders* (hair shavers), because it is believed that they sneak into beds at night and snip off people's hair with their jaws. In some parts of the Middle East, locals (and perhaps U.S. military personnel) are convinced that camel spiders grow up to two feet (sixty centimeters) long and can jump up onto a large mammal such as a horse or a camel and bring it down with those powerful jaws in order to burrow into its guts. Although solifuges are formidable predators, such tales of their prowess are entirely fictional.

Like most other arachnids, solifuges have two major body segments: a prosoma (also called the propeltidium), which combines the head and thorax, and an opisthosoma (also called the abdomen). The overall length of these animals ranges from slightly less than one inch (two and a half centimeters) to more than four inches (ten centimeters), including the legs. Attached to the prosoma are the chelicerae (or jaws), as well as a pair of leg-like pedipalps and four pairs of legs. The pedipalps are covered in setae (sensory hairs) that probably serve to detect vibrations, odors, and chemical cues in the environment.

Camel spiders are agile predators, using their great speed to run down prey, including insects, reptiles, and small mammals. *Eremobates pallipes* feeding on a cricket, photographed by Jen Rowsell.

These appendages, typically held extended in front of the body when the solifuge is in motion, are used in capturing prey and burrowing; they are also the means by which the male grasps the female during copulation. Dangling from the underside of the rear legs, close to the base, are racquet-shaped malleoli, which are thought to be sensitive organs of smell. With just two simple eyes on the prosoma, solifuges have poor vision and are likely capable of perceiving light intensity and little else.

Solifuges show a strong response to any sudden stimulus. When threatened, a camel spider rises on its legs, rocks its body back and forth, raises its pedipalps and first legs, and opens its chelicerae. Although solifuges do not possess venom glands and thus can inflict only minor pinches, their behavior can easily be misinterpreted. Species in some families have sound-producing ridges located on the inner surfaces of the chelicerae and have been reported to "hiss" alarmingly when disturbed.

Camel spiders are cursorial hunters, that is, they run down their prey. They are known for their speed, with some individuals clocked at around ten miles (sixteen kilometers) per hour. They will attack reptiles, small mammals, birds, and invertebrates of all kinds, including other solifuges. The pedipalps, the chelicerae, and, in some species, the first legs are used in the act of capture. Specialized eversible (inflatable) suctorial organs on the final segment of the pedipalps allow solifuges to tightly grip smooth surfaces, such as the exoskeletons of their insect prey. Although they have been documented scavenging freshly killed invertebrates, they feed mostly on live prey, driving their chelicerae into the soft body parts with a rotational, macerating action and reducing the prey to liquid via external digestion.

Some species are arboreal, at least to some degree, while others can climb a variety of vertical surfaces to hunt. Still other species have been reported inhabiting termite nests and mangrove stalks. Solifuges secrete themselves under or in all manner of items, including rocks, boards, logs, cow chips, rodent burrows, and the stalks or stems of shrubs and bushes. At night, camel spiders can be found in illuminated areas, hunting for insects attracted to the lights. Many species excavate burrows in which to spend inactive periods; these may be simply a shallow divot in the soil or as deep as twelve inches (thirty centimeters), and may be plugged or unplugged. A burrow protects the solifuge from the sun, predators, and desiccation, and also provides shelter for ecdysis (molting), feeding, and egg laying. Many solifuge species burrow in desert flood plains where flash floods are common; remarkably, individuals can survive up to two hours immersed in water.

The nature of reproductive behavior has been documented for only a few species in a few families (Solpugidae, Galeodidae, Eremobatidae, and Ammotrechidae), but in those species the behavior is similar. When a female first comes into contact with a male, she falls into a trance-like state. No one knows what triggers this female quiescence. During this time she is physically pliant, allowing the male to hold her body with the suctorial organs on his pedipalps and twist it so that his chelicerae are situated opposite her gonopore, or genital opening. He then inserts his upper jaws (the fixed fingers of the chelicerae) into her

body, vigorously chewing and kneading her genital area, and presumably preparing her for sperm transfer (and perhaps removing a competitor's sperm). The male then releases a sperm packet, or spermatophore, which he either picks up with his chelicerae and places at the opening of her gonopore or places directly on her opening from his own genital opening.

Once the spermatophore has been placed inside the female, the male reinserts his chelicerae into her body and resumes his chewing action, presumably to facilitate release of sperm from the spermatophore. On a good day, he will disengage from the female and flee the area as she emerges from her mating trance. On a bad day, the female revives midway through his amorous activities, and on such occasions she tends to inflict lethal wounds to his prosoma before proceeding to dine on her former partner. The arachnid mating world is fraught with peril, particularly in the case of camel spiders.

Females deposit their eggs in burrows, in quantities ranging from fifty to two hundred. Almost all studies of the early life stages have been done in laboratories. The life cycle of those solifuges studied seems to be univoltine (one generation per year); however, some isolated studies are suggestive of two- to four-year life spans. Newly hatched camel spiders appear translucent, shiny, and white, and remain massed together, wriggling slightly. Their chelicerae are poorly formed and still soft. The legs are not completely segmented. Eye spots are formed but the eye tubercle is not.

In laboratory settings the time from hatching to first instar ranges from nine to twelve days. First instar nymphs resemble adults except for the absence of the malleoli on the rear legs. Remaining clustered, these nymphs are more mobile but appear not to feed until the molt to the second instar occurs, after which activity increases and aggressive behavior is apparent. At this stage, the young solifuges begin to hunt and

These large arachnids possess impressive chelicerae (jaws), but do not have venom glands. Photographed in Mozambique by Piotr Naskrecki.

Camel spider nymphs clustered around hatched and unhatched eggs. These nymphal solifuges are relatively immobile and incapable of feeding. Photograph by Paula Cushing.

capture whatever small prey is available (including each other). Only *Eremobates mormonus* has been successfully reared in the laboratory from egg to adult, with eight instars reported; estimates for species in other families range from four to eight instars before adulthood. The time of development for each stage depends on temperature, relative humidity, and time of hatching.

The few species of solifuges that have been studied in any detail appear to be both habitat-specific and range-restricted. This suggests that these animals are quite vulnerable to habitat degradation, which increases their risk of extinction and also makes them valuable indicator species for desert environments. In many regions, the transformation of deserts into irrigated agricultural fields or the increasing spread of urban development has greatly reduced habitat availability and quality, and it is very possible that species of camel spiders that we don't even know about have already been driven out of existence.

Sadly, though camel spiders are an integral part of the desert community, they receive no formal protection and many more species may well disappear before being described. As with all such fascinating members of our Earth's biodiversity, they deserve attention before it's too late.

Paula E. Cushing, Ph.D. is the curator of invertebrate zoology at the Denver Museum of Nature & Science.

Jack O. Brookhart is a research associate at the Denver Museum of Nature & Science and has been studying camel spiders since the 1960s, making him one of the world's foremost authorities on this group of arachnids.

Jen Rowsell is completing her master's degree at West Texas A&M University, where she is studying various aspects of camel spider behavior, including courtship and mating.

CONSERVATION SPOTLIGHT

Karen Oberhauser: Tireless Champion for Monarch Butterflies

If there were a list of the top five people in the world who are working to protect monarch butterflies, Karen Oberhauser would undoubtedly be on it. An unassuming powerhouse of monarch conservation, Karen is a scientist of the highest caliber, an educator who has taught many thousands of people about monarchs, and a conservationist who regularly works with other scientists, federal and state land managers, and policy makers to protect monarchs and their habitat.

Karen has been studying monarchs since 1984. Her research in collaboration with John Pleasants of Iowa State University has helped us understand how widespread herbicide use has contributed to monarch butterfly declines over the past decade. This work has been central to raising awareness of the large role that habitat plays in monarch survival.

Through her work as a professor in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota, Karen leads a research group—the U of M Monarch Lab—that conducts research on several aspects of monarch butterfly ecology. Over the years, this group has included dozens of graduate and undergraduate students, many of whom are now leaders in conservation research and education. Their work has addressed the butterflies' reproductive ecology, a protozoan parasite of monarchs (commonly called OE), factors affecting the distribution and abundance of caterpillars, and risks posed by climate change, insecticide use, and genetically modified crops.

The U of M Monarch Lab has also created a pair of outreach programs, Monarchs in the Classroom and the Monarch Larva Monitoring Project. Monarchs in the Classroom promotes inquiry-based education through research opportunities and original curricula, and organizes an annual Insect Fair to spotlight student research. The Monarch Larva Monitoring Project, now entering its eighteenth year, has many hundreds of volunteer citizen scientists collecting data on monarch caterpillars and milkweed habitat at more than nine hundred locations in the United States, Canada, and Mexico. The central goal of the project is to better understand how and why monarch populations vary in time and space, with a focus on monarch distribution and abundance during the breeding season in North America.

As the director of both programs, Karen has engaged people directly in science and conservation, changing hearts and minds while establishing an ever-expanding body of support for these important animals.

Her influence was officially recognized in June of last year, when Karen was named a White House Champion of Change for her efforts in monarch butterfly citizen science and her role as director of the Monarch Larva Monitoring Project. In announcing this honor, the White House said "Karen is passion-

ate about the conservation of the world's biodiversity, and believes that nurturing connections between humans and the natural world promotes meaningful conservation action."

Karen's work (and influence) goes beyond the laboratory and classroom. She regularly makes the case that we need to work to protect these animals. Karen is the principal author of the North American Monarch Conservation Plan. Canada, Mexico and the United States joined to produce this long-term cooperative agenda for conserving the monarch and its migratory phenomena. The plan outlines critical actions needed for the conservation of monarchs and details habitat conservation and restoration actions that are necessary for monarch survival.

Karen is actively engaged in monarch conservation organizations. She is a founding member of the Monarch Joint Venture, which works with a variety of partners, including the U.S. Forest Service International Programs and the Xerces Society, to implement the North American Monarch Conservation Plan and to educate people about the plight of monarchs. Karen and Scott Hoffman Black, executive director of the Xerces Society, serve as co-chairs of the Monarch Joint Venture. In addition, Karen is a long-time board member of the Monarch Butterfly Fund and is now, we are pleased to say, one of the Xerces Society's scientific advisors.

It is seldom that a person achieves so much in either academia or conservation. To have accomplished so much in both is rare. Karen deserves the accolades she has received, and has earned our gratitude for her determined efforts on behalf of monarch butterflies.

Karen Oberhauser has dedicated herself to researching and protecting monarch butterflies. Thanks to her, thousands of people are involved in conserving monarchs—and the butterflies are a little safer. Photograph by Michelle Solensky.

INVERTEBRATE NOTES

Chemical Found in Sunscreens Is Toxic to Corals

Research by the National Oceanic and Atmospheric Administration and partners suggests that benzophenone-2 (BP-2), added to sunscreen to protect against UV rays, is having a toxic effect on coral reefs. Researchers showed that BP-2 can kill juvenile corals, cause coral bleaching, and induce mutations. The chemical is not typically removed through water treatment, and is often found in the waters surrounding nearshore reefs.

The study's lead author, Craig Downs, believes that working with manufacturers, creating more environmentally sustainable products, and educating consumers might help reduce BP-2's potential impact on coral reefs. (Downs, C. A., et al., 2014. Toxicological effects of the sunscreen UV filter, benzophenone-2, on planulae and in vitro cells of the coral, *Stylophora pistillata*. *Ecotoxicology* 23:175–191.)

Mysterious Syndrome Is Causing Sea Stars to Come Apart

Sea Star Wasting Syndrome is causing North American sea stars to self-destruct, and researchers are unsure of its cause. First observed in Washington state in summer 2013, the syndrome has since spread along both the East and West Coasts. An affected sea star first develops white lesions; next, its arms pull away from its body, exposing its internal organs and quickly resulting in death. No part of the diseased star regenerates.

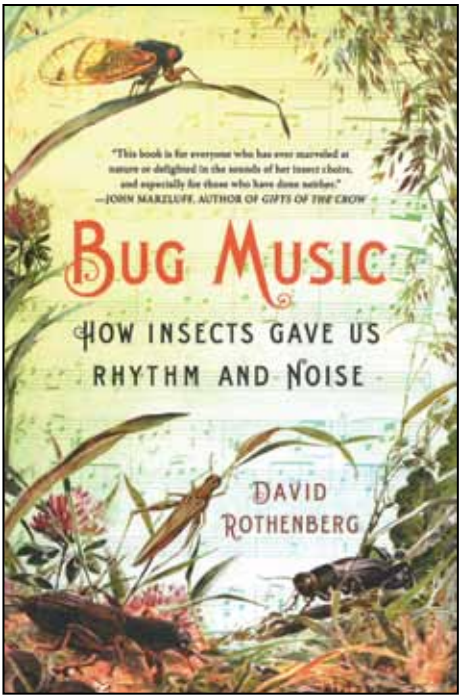
Voracious predators, sea stars are a keystone species and population declines could cause significant environmental changes. Researchers at the University of California at Santa Cruz are engaging scientists and citizen scientists to help track the syndrome's geographical spread. Their data and information about monitoring can be found at: http://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting/.

Pollinator Habitat on Farm Fields Helps Both Bees and Crops

A new study suggests that increasing land set-asides in farm fields in order to increase pollinator habitat positively impacts both wild pollinators and the crops that depend upon them.

Researchers at Rutgers University sought to understand the spatial scale at which land use affects pollinators and pollination services, by examining bee populations and crop pollination at farms with varied levels of agricultural land cover. They found that bee numbers and pollination services were both strongly influenced by the presence or absence of habitat within crop fields. (Benjamin, F. E., J. R. Reilly, and R. Winfree. 2014. Pollinator body size mediates the scale at which land use drives crop pollination services. *Journal of Applied Ecology*, early view online.)

New Books



Tiny, abundant, and practically omnipresent, insects are one of the most accessible parts of nature. Though we often study insects in an objective and scientific manner, we also engage with them on a personal level. Two charming new books deal with our more intimate interactions with invertebrates.

A Sting in the Tale (Jonathan Cape) opens with bumble bee expert Dave Goulson's good-natured (though often misguided) childhood attempts at conservation. This youthful fascination grew into his life's work, and the book chronicles his bumble bee conservation efforts. Weaving together the fascinating peculiarities of bumble bees and a narrative that spans both continents and decades, *A Sting in the Tale* mixes science, humor, and an impassioned call to protect our world's bumble bees.

In *Bug Music: How Insects Gave Us Rhythm and Noise* (St. Martin's Press), jazz musician and philosopher David Rothenberg puts forth an intriguing theory: that millennia spent listening to insects has shaped our collective sense of rhythm and music. The book follows Rothenberg as he plays saxophone with seventeen-year cicadas, visits a cricket orchestra in Stockholm, and spends an evening with a singer and a chorus of katydids in the Hudson Valley. Throughout, Rothenberg offers a unique meditation on our relationship with insects and the subtle ways these creatures may shape both our culture and our psyches.

Honey Bee Diseases Affecting Wild Bumble Bees

Researchers in Britain have found that wild bumble bees are being infected by two diseases harbored by honey bees, deformed wing virus and *Nosema ceranae*. They report that the prevalence of the diseases in bumble bees and honey bees is linked, and that honey bees may be the source of the infections.

Though their data are drawn from the United Kingdom, the scientists believe this phenomenon is taking place globally. They suggest that improved pathogen control in managed bee species is necessary to protect native pollinators, and that new policies to manage diseases must take both managed and wild bees into account. (Fürst, M. A., et al., 2014. Disease associations between honeybees and bumblebees as a threat to wild pollinators. *Nature* 506:364–366.)

STAFF PROFILE

Matthew Shepherd, Communications Director

What got you interested in insects? My father took an interest in butterflies, and as a child I absorbed that. Later, when I was running a conservation program in Essex, England, insects became an obsession. We restored many small sites: meadows for ants and butterflies, woodlands for butterflies and beetles, heathlands for bees, ponds for dragonflies.

How did you hear of the Xerces Society? When I moved to this country in the late 1990s, I came to Oregon and began looking for a job. Someone suggested that I do an informational interview with Melody Mackey Allen, then Xerces' executive director. Over coffee we discovered that I had skills and experience that could help Xerces' projects and Melody offered me part-time work.

What made you want to work here? Connecting people with their environment—and converting that into action—has long been a passion of mine. Working at Xerces allows me to do that, while protecting the animals that are most important. And I love working for a nonprofit. I've stayed here for fifteen years because it has been so satisfying to be part of such a dynamic organization and contribute to its growth and achievements.

Who's in your family? My wife, Karen—she's the reason I moved to the United States—and our two kids, Edie and Julian, plus various small pets.

What do you do for relaxation? Hike, read, play games with my family, garden, listen to music, watch wildlife, and look for shapes in the clouds.

Which books are you currently reading? There are two: *Bugs Britannica*, by Peter Marren and Richard Mabey, and *Adam Bede*, by George Eliot.

Who is (or was) your environmental hero? John Ray, a seventeenth-century naturalist who could be considered the father of entomology, and who was born and did his studies in the same area of Essex where I lived and worked. And Jonathon Porritt, who, as director of Friends of the Earth during the 1980s, inspired me to become an environmental advocate.

Where did you study? I was educated in Britain, where I completed a bachelor of science degree at Plymouth Polytechnic (now Plymouth University) and a master of science at Silsoe College (now Cranfield University).

Bumble Bee Watch Is Off and Running

In January, the BumbleBeeWatch.org web site was launched, creating a new way for people to be directly involved in protecting bumble bees throughout North America. Bumble Bee Watch enables people to connect with experts and other enthusiasts to identify bumble bees they see and to learn about their ecology; by submitting photographs, these citizen scientists can help to build a comprehensive picture of where bumble bees are thriving and where they need help.

Bumble bees are essential to wildlands, gardens, and farms. Many recent reports suggest that we may be losing their familiar buzz from our summer landscapes due to habitat loss, insecticide use, disease, and climate change. In particular, an analysis of bumble bee sightings and museum records show that a third of North America's species are in decline. Action is needed to identify and protect those species at greatest risk, and over the last several years we have engaged citizen scientists to help follow a handful of priority bee species. Bumble Bee Watch enables scientists from Xerces and our partner institutions to draw upon an increasing number of individuals who can contribute to this work.

Bumble Bee Watch is a partnership between the Xerces Society, Wildlife Preservation Canada, the University of Ottawa, the Montreal Insectarium, the Natural History Museum in London, and BeeSpotter.

Learn about North American bumble bees—and help protect them—by participating in Bumble Bee Watch. Photograph by Matthew Shepherd.

A Successful Year for the Migratory Dragonfly Partnership

The Migratory Dragonfly Project, a two-year-old partnership between dragonfly experts, nongovernmental programs, academic institutions, and federal agencies from the United States, Mexico, and Canada, works to better understand North America's migrating dragonflies and to promote conservation of the wetland habitat on which they rely. Funding is provided by the U.S. Forest Service International Programs.

The partnership works via three citizen-science projects. Pond Watch is place-based, with volunteers regularly reporting on sightings of migratory species at particular locations. Migration Monitoring is seasonal, tracking the spring and fall movements of dragonflies. Volunteers with the Stable Isotope Project collect samples for laboratory analysis of hydrogen isotopes to assess the distance a dragonfly travels from the site where it developed into an adult.

In the past year, the MDP has grown dramatically: More than twice as many records were submitted to the MDP website in 2013 as there were in 2012, and the number of migration reports increased by 700 percent! We forged new partnerships with the Hawk Migration Association of North America (as migrating birds and dragonflies follow similar routes), master naturalists groups, friends organizations of National Wildlife Refuges, and Espacios Naturales y Desarrollo Sustentable (ENDESU) in Mexico. We created new resources, including backyard habitat guidelines and a Spanish-language field guide.

These efforts have already yielded insight into dragonfly migration. Reports from volunteers are helping us understand patterns of dragonfly movement and visualize patterns of arrival

Sightings of the common green darner (*Anax junius*) reported by participants in citizen-science projects of the Migratory Dragonfly Partnership have expanded knowledge of the timing and extent of the species' movements. Photograph by Bryan E. Reynolds.

for different species at ponds across the continent. We appreciate the dedication of our volunteers and partners as we find answers (and develop new questions) in solving the puzzle of dragonfly migration in North America.

Xerces Expands Its Partnerships in the Business Community

The Xerces Society is proud to have a growing range of partnerships with businesses that share our environmental goals. These relationships expand our reach and provide support for our conservation programs.

Whole Foods Market has been a corporate partner for three years. We're excited to say that in June Whole Foods Market and its vendors will again be hosting Share the Buzz, an event that features events and promotions in many of the company's stores, as well as sales of pollinator-dependent products benefiting Xerces.

In addition, two companies are selling products with a Xerces tie-in exclusively at Whole Foods Market. The Suja Juice Elements Cause Collective features twelve nonprofits, each with a smoothie that raises money for the organization; the Jasmine Tea flavor supports Xerces. The second company is Cascadian Farm. Look for their limited-edition Honey Almond Medley cereal, on the back of which you'll find information about our Bring Back the Pollinators campaign.

Xerces is a partner in Endangered Species Chocolate's 10% GiveBack program, which supports nonprofits with a portion of its revenue. Endangered Species has just released a filled bar—Blueberry Vanilla Crème Filled Dark Chocolate—that features the rusty patched bumble bee. Inside the wrapper is a profile of this imperiled species, providing information about how to help Xerces protect this and other bumble bees.

Xerces also has friends in the world of beauty. Chantecaille, a luxury skincare company, has released the Save the Bees palette of four gentle shades of makeup; 5 percent of proceeds support Xerces programs. And we have a partnership with Aveda, which has hosted pollinator-awareness days at its Experience Centers across the United States.

Our thanks to these companies and our other business partners for supporting our work and making a public commitment to saving bees. Through their efforts, messages about the importance of insects and ways to care for them are reaching thousands of new people.

Pollinator Conservation Short Courses Reach Fiftieth State!

When we began presenting our Pollinator Conservation Short Courses a few years ago, the aim was to bring them to all fifty U.S. states. We reached that target on February 6 of this year with a presentation in Hawaii. The one-day courses have been widely acclaimed, with registration typically filling rapidly; in many states we have had to present several courses to accommodate all of the people who wish to attend. Given the strong desire for additional short courses, we will be returning to many states in the near future. We are also implementing a new series of short courses on conservation biocontrol.

The Xerces Society's Pollinator Conservation Short Courses have trained hundreds of farmers and agency conservationists in ways to provide flower-rich habitats to sustain bees and other beneficial insects. Western bumble bee (*Bombus occidentalis*) foraging on goldenrod (*Solidago*), photographed by Rich Hatfield.

These courses have been made possible through the support of Sustainable Agriculture and Education grants in every region of the United States and with help from our partners at the Natural Resources Conservation Service. Now with staff scientists in five states from California to New Jersey, our pollinator conservation team is educating people about how to restore, enhance, and manage farm landscapes for the benefit of native pollinators.

This team has just expanded with the addition of Anne Stine, who comes to us from the Nature Conservancy in Nebraska. Based in Texas, Anne will support our outreach and habitat restoration work in the Central Plains as a joint Xerces/USDA-NRCS pollinator conservation specialist.

Xerces Establishes Pesticide Program

The Xerces Society has initiated a new conservation program focused on pesticides. Pesticide reduction is not a new issue of concern for us. We have worked with great success to reduce the area and impact on nontarget animals of grasshopper spraying in the Intermountain West, and in the past couple of years have become a leading voice on the impacts of neonicotinoid insecticides on bees and other beneficial insects and on ways to manage mosquitoes in wetlands with minimum impact to wildlife. Until now, though, we have not had dedicated staff time to work on these issues. That changed in November with the arrival of our new pesticide specialist, Aimee Code, formerly of the Northwest Center for Alternatives to Pesticides.

Aimee is working with communities across the United States to establish better regulations for neonicotinoid in-

secticides, and she and Celeste Mazzacano, director of our Aquatic Conservation Program, are collaborating on ways to address mosquito management at wetlands nationwide.

In the months since our pesticide program began, Xerces has worked with a group of organizations to promote the Save Oregon's Pollinators Act. Sponsored in the Oregon legislature by Representative Jeff Reardon and signed into law on March 6, 2014, this Act is the first statewide legislation specifically intended to protect bees from neonicotinoid insecticides. The bill makes instruction on protecting pollinators a requirement for pesticide applicator training and adds pollinator protection information to applicator licensing exams. The bill also creates a task force charged with bringing to Oregon's 2015 legislative session new legislation to address the threat that pesticides pose to pollinator health. Although Xerces supports the Save Oregon's Pollinators Act, we believe that it does not go far enough. In the coming months, our goal will be to work with the task force to come up with meaningful legislation that will more effectively address this important issue.

Scott Hoffman Black Assumes Expanded Role at the IUCN

As an indication of the growing influence of the Xerces Society, Scott Hoffman Black, our executive director, has been appointed deputy chair of the International Union for Conservation of Nature's Species Survival Commission's Invertebrate Conservation Sub-Committee. The subcommittee oversees the IUCN's terrestrial invertebrate specialist groups. Scott has chaired the IUCN's SSC Butterfly Specialist Group for several years, and Simon Stuart, chair of the SSC, invited him to take on the additional responsibility.

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Specialized communities of tubeworms and mussels form around deepwater cold seeps, creating dense beds that provide shelter to shrimps and other animals. Photograph courtesy NOAA Photo Library (Aquapix and Expedition to the Deep Slope 2007).

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On the cover: Octocorals are an extremely diverse group of soft corals that are an important component of many deepwater, hard-bottom communities. Their biology is not well understood, and conservation of these species hinges on more research being done. Photograph courtesy NOAA Photo Library (Aquapix and Expedition to the Deep Slope 2007).