The Evening Primrose, the Hawkmoth, and the *Mompha* Moth: An Evolutionary Love Triangle

In August 2013, as dusk fell across the world's largest deposit of gypsum sand, just west of Alamogordo, New Mexico, in White Sands National Monument, Krissa Skogen, Ph.D., a conservation scientist at the Chicago Botanic Garden, knelt before a backlit, fluttering bed sheet stretched over a rectangular frame of PVC pipe: a tent-sized moth trap.

With her headlamp aglow, Dr. Skogen was awaiting the moonlit arrival of what she hoped would be scores of nectar-hungry hawkmoths (Sphingidae)—busy, hummingbird-like insects, roughly the size of a human thumb, which fly up to 20 miles a night, allured by the floral scent of members of the evening primrose family (Onagraceae). At Skogen's side was Chris Martine, the David Burpee Chair in Plant Genetics and Research at Bucknell University, and creator and host of *Plants Are Cool, Too!,* a YouTube series dedicated to capturing on film what the title would suggest—the fascinating stories of plants and the plant scientists who study them in the field.

Skogen, along with Garden conservation scientists Jeremie Fant, Ph.D., and Norman Wickett, Ph.D., and research collaborators at Amherst College, Cornell University, and the Smithsonian Institution, have quite a story—an evolutionary unsolved mystery of wildflower romance, floral diversification, and pollinator ecology spanning western North America. Through a five-year, $2 million grant from the National Science Foundation (NSF), the group is producing one of the world's only studies of scent-driven, geographic diversification in groups of interacting organisms—namely, hawkmoths, bees, the *Mompha* moth, and the evening primrose.

"What we're trying to figure out is why so many flowering plants—angiosperms— radiated at the same time as insects. Plants can't move, so they have to find a way to move their gametes (reproductive cells). Pollen moves in a number of ways: wind

Sphinx chersis, the great ash sphinx moth, was collected visiting lavender-leaf sundrops *(Oenothera lavandulifolia)* in southwestern Colorado.

pollination, animal dispersal, and other ways. Anything plants can do to reward pollinators, whether it involves shape, visual, or olfactory cues, can help improve their chances for survival," Skogen said.

The study is novel not only for its ecological breadth, but also its investigation of diversification at population, species, and higher taxonomic levels. While government agencies, universities, and conservation organizations often invest their resources to preserve iconic, charismatic animals whose numbers are dwindling—like the spotted owl—such a narrow focus ignores a more complex picture of interdependency and co-occurring selection among entire groups of organisms and plant communities.

In fact, one reason the evening primrose may bloom at night, Skogen said, is because, over hundreds of thousands of years, doing so improved the likelihood it would reproduce. Since hawkmoths fly great distances over the hot desert, they do so at night during cooler temperatures to conserve energy. By opening its petals in the evening, with a greater chance of visitation by the hawkmoth, the evening primrose may enhance its fitness through improved seed set, pollen spread, and fruit production.

In all of this, there is an unmistakable whiff of desert romance. The hawkmoth waits until nighttime to fly in on papery wings and dip its long, tongue-like proboscis into the mouth of the evening primrose, feeding on the flower's sugary nectar. Seldom, though, does a hawkmoth leave without a trace. While extracting nectar, the hawkmoth will brush against the flower's pollen and carry a signature of the plant's genetic material, in the form of pollen, to other flowers.

"Pollinators don't know, likely, that they are pollinating; they are just looking for food. Flowers have all these color and scent tricks to attract pollinators to an area. It's like a big, huge McDonald's sign on the side of the highway advertising to a pollinator where the food is," Skogen said.

Postdoctoral researcher Rick Overson attaches a vacuum pump to a flower of Howard's evening primrose *(Oenothera howardii)* to collect floral scent at a site northwest of Green River, Utah.

These signals, however, are freely available and attract other, less desirable, suitors—one of them, the *Mompha* moth, a floral predator whose larvae may feed on flower buds or seeds, thereby reducing the number of offspring the evening primrose produces. What emerges is a kind of evolutionary love triangle involving trade-offs, and a central question: which combination of smell, color, and shape yields the best payoff for a particular flower, population, or species?

Over the next five years, the research team will collect nectar, pollen, and scent samples from 15 focal species across the western United States—delicate work that involves X-Acto knives, microcapillary tubes, and intimate contact with plants and pollinators. Back in the Harris Family Foundation Plant Genetics Laboratory, Drs. Fant and Wickett will use DNA extractions and genotyping to compare molecular differences among bees, hawkmoths, and evening primrose plants, with the hope of opening a new pathway in evolutionary biology.

"It's interesting not just in terms of the evolutionary history of species, but also at the population level, where populations may be reproductively isolated from one another. Because hawkmoths are traveling long distances you would think that there would be a lot of genetic mixing, but it's possible that there is another layer—that only *Mompha*-resistant individuals can survive and reproduce in certain areas. We suspect that what we see at the population and species level may be influencing evolutionary processes at higher taxonomic levels, as well," Wickett said.

With a total of $1.5 million in grant funding earmarked for Garden-led research activities, the study represents the Chicago Botanic Garden's largest National Science Foundation grant to date, and a bold stride forward for an emergent, internationally expanding science program. In collaboration with Northwestern University, the Garden's science program annually engages more than 200 scientists, graduate students, interns, and postdoctoral researchers within the Daniel F. and Ada L. Rice Plant Conservation Science Center, at field sites throughout the United States, and in more than 30 countries.