Pollinators

Pollinators in peril? A multipark approach to evaluating bee communities in habitats vulnerable to effects from climate change

By Jessica Rykken, Ann Rodman, Sam Droege, and Ralph Grundel

CAN YOU NAME FIVE BEES IN your park? Ten? Twenty? Will they all be there 50 years from now? We know that pollinators are key to maintaining healthy ecosystems—from managed almond orchards to wild mountain meadows—and we have heard about dramatic population declines of the agricultural workhorse, the honey bee, yet what do we really know about the remarkable diversity and resilience of native bees in our national parks?

A large proportion of flowering plants in most parks rely on insect pollinators for successful reproduction, and native bees are almost always the most efficient and diverse of these insects, with 3,604 described species in North America north of Mexico, and what are thought to be another 400 undescribed ones. Bees are known to be at risk from various human-mediated threats, such as habitat loss and alteration, pesticides, introduced parasites, and invasive plant and insect species. Climate change also poses a significant risk to native bees, with potential consequences including range shifts (especially upslope or northward), population declines, and mismatches in the phenology of plant-pollinator relationships.

At particular risk are bee communities (including rare and endemic species) in habitats most vulnerable to effects from warming temperatures, altered climates, and rising seas. These include high-elevation meadows, inland arid areas, and coastal dunes—in other words, many of the iconic landscapes protected in our national parks. In fact, the geographically and ecologically diverse landscapes preserved and protected by the National Park Service provide an ideal natural laboratory in which to investigate large-scale patterns of bee distribution in sensitive habitats and to model how strongly climate change may affect these patterns.

In 2010, collaborators from the National Park Service (Ann Rodman, Yellowstone National Park), USGS (Sam Droege and Ralph Grundel), and Harvard University (Jessica Rykken) were awarded funding from the NPS Climate Change Response Program to launch just such an investigation in almost 50 units of the National Park System (fig. 1). The main objectives of this multiyear project were to:

1. Compare bee communities in three "vulnerable" habitats (high elevation, inland arid, coastal) and paired "common" habitats, representative of the landscape matrix, in order to determine whether vulnerable habitats

Figure 1. Forty-six parks in the National Park System participated in the bee inventory research.

have a distinctive bee fauna that may be at higher risk under climate change scenarios.

2. Inform natural resource managers at each park about the bee fauna at their paired sites, including the presence of rare and endemic species, and make suggestions for active management strategies to promote native bee habitat if warranted.

3. Increase awareness among park natural resource staffs, interpreters, and visitors of native bee diversity and natural history, the essential role of bees in maintaining healthy ecosystems, and potential threats from climate change to pollinator-dependent ecosystems.

The challenge of a multipark approach

The project was designed so that the cost and effort of sampling for each park would be minimal, while the information provided by uniformly collected bee data from dozens of parks across the continent would be of unprecedented scope and power. Each park was responsible for selecting a pair of vulnerable and common sites and then sampling both sites five times between the earliest spring flowering and the end of the blooming period in the fall. Sampling procedures were designed to be simple, repeatable, and volunteer-friendly. At each of the two sites, 30 "bee bowls" were set out along a transect, spaced 5 m (16 ft) apart. The cups were painted blue, yellow, and white to resemble flowers and attract bees (fig. 2). Once inside the "flower," bees were trapped in soapy water. Ideally, bowls were left out for 24 hours when conditions were calm and sunny. Bees were then collected, labeled, bagged, and sent off for identification. To facilitate communication between project organizers and participating parks, a "bees in parks" e-mail list was set up early on. This was useful for discussions about where and when to sample (which varied greatly depending on park location, habitat, and local climate) and, later, to pass along interesting bee discoveries directly from bee biologists to parks.

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Figure 2. Collecting bees involves pouring the contents from one of the painted "bee bowls" through a strainer. Contents from all 30 bowls of a transect were combined, transferred to a plastic bag, and shipped to the bee lab in Maryland.

As is commonly the case with insect biodiversity studies, collecting is the easy part. One of the largest challenges for a project of this scale is preparing, identifying, and databasing the tens of thousands of specimens that can be sampled in a relatively short period of time. With bees coming in from Alaska to Maine, southern California to Florida, and everywhere in between (fig. 1), the potential number of specimens and the pool of possible species (several thousand) were somewhere between thrilling and completely overwhelming. USGS biologist Sam Droege took on the herculean task of processing all the bees at his Bee Inventory and Monitoring Lab at the Patuxent Wildlife Research Center in Beltsville, Maryland, where his efficiency rating ("bees per minute") rises ever higher in the nimble hands of high school and college students. Identification of the bulk of the eastern bees and some of the western bees was also completed within his lab; however, most of the western bees were sent to the USDA Bee Biology and Systematics Lab in Logan, Utah.

Preliminary results: Many cool bees!

A total of 46 national park units participated in the study (fig. 1). These included 30 national parks, preserves, and monuments; 10 national lakeshores and seashores; and six national recreation areas, historical parks, and parkways. All NPS regions in the lower 48 states (with the exception of the National Capital Region) were well represented, as were Alaska and the Virgin Islands. Several parks without any of the target vulnerable habitats also participated in order to enhance their knowledge of local bees in other sensitive habitats. In Alaskan parks, all habitats were considered potentially vulnerable to

Figure 3. The eastern sweat bee, *Augochlorella aurata*, one of the most common bees in eastern North America, and the most abundant bee in the study. Color varies from metallic deep purple (above left) (Cumberland Island, Ga.) to green (above right) (Md.), depending on the region.

Figure 4. A dorsal shot of a sweat bee, *Lasioglossum marinum*, from Fort Matanzas (Fla.). As its name suggests, this bee is a coastal dune specialist and builds its nest in deep sand.

Figure 5. The mason bee, *Dianthidium simile*, is a rare dune specialist, found on the shores of the Great Lakes (this one is from Sleeping Bear Dunes, Mich.). Females build nests at the base of grass clumps; cells are constructed of conifer resin and sand grains.

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climate change because of their northern location. Many parks also placed a transect near a visitor center for interpretive value, and some parks added transects in additional habitats. Among them, the 46 parks ran an impressive 809 bee bowl transects, sampling more than 43,000 bees from 2010 to 2013.

Full sets of results have been completed for some parks and regions (mostly in the eastern and midwestern United States), but the enormous task of identifying all the western bees has fallen to a very few western taxonomists, and many of these identifications are still pending. Additionally, there are some taxa that are so diverse and difficult to separate (e.g., the diabolical subgenus *Dialictus*, with almost 100 species in eastern North America alone) that some or all of these bees have been passed on to individual specialists around the country (see acknowledgments). As is also often the case with insect biodiversity studies, taxonomists are in short supply and in high demand. To date, more than 25,000 specimens have been identified, representing 43 genera and approximately 685 species. Among these are many interesting discoveries.

Some bee species are noteworthy because they are so abundant or widespread. Not surprisingly, the nonnative honey bee (*Apis mellifera*) showed up in relatively large numbers in half the parks surveyed, all across the continent. Other cosmopolitan "weedy" (but native) species included the two sweat bees *Halictus confusus* and *H. rubicundus*, both found in 17 parks, the latter from Redwood (Calif.) to Glacier (Mont.) to Assateague Island (Md.). The most commonly collected bee overall, with 2,012 individuals (4.6% of the bee total), was *Augochlorella aurata*, a brilliant green sweat bee found in 17 parks, from Big Thicket (Tex.) eastward (fig. 3). In a previous study at Indiana Dunes (Grundel et al. 2011), this species was also the most frequently captured bee, making up 16% of all bees surveyed, and was observed on more than 60 plant species, suggesting that this generalist forager is a pollination workhorse in the eastern parks.

Of greater interest to this project were the habitat specialists, some of which were also very abundant across parks. For instance, more than 1,000 individuals of *Lasioglossum marinum*, a coastal dune specialist, were found in seven parks down the Atlantic coast, from Boston Harbor Islands (Mass.) to Biscayne (Fla.) (fig. 4). In contrast, the polyester bee *Colletes brevicornis*, found only in the dune site at Assateague Island (Md.), is a much rarer dune specialist restricted to the Atlantic coastal plain. The mason bees *Dianthidium simile* (fig. 5) and *Osmia michiganensis* are also rare dune specialists, but are found on the shores of the Great Lakes. These and other species that depend on deep sand for nesting suggest that dune habitats of lakeshores and seashores do have a distinctive fauna, including rare and endemic species (see sidebar, page 88). If sea and lake levels change with warming climates, or extreme weather events like Hurricane Sandy reshape coastlines, these bee communities are at risk of losing habitat.

As the two other focal habitats (inland arid and high elevation, figs. 6 and 7) are concentrated in the western United States, we are still awaiting species data, and thus patterns of bee diversity across these landscapes are not yet clear. However, interesting discoveries have already been made. For instance, the digger bee, *Habropoda pallida*, found at Mojave (Calif.), is a dune specialist from the desert Southwest, thought to be a specialist on creosote bush. The tiny desert-dwelling mining bee, *Perdita albihirta*, collected at Petrified Forest (Ariz.), is not well-known, but is probably a pollen specialist like many of its relatives (fig. 8). Michael Orr from the Logan bee lab, who has been working with many of the western bees, has emphasized

Figure 8 (above). This tiny mining bee, *Perdita albihirta geraeae*, collected at Petrified Forest (Ariz.), measures just a few millimeters long.

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Figure 9. Prior to being collected at Canaveral National Seashore (Fla.) in 2013, there had been no collection records for the southeastern endemic polyester bee, *Colletes titusensis*, since 1938.

the importance of collecting in under-sampled areas (i.e., most of our national parks), and illustrates this point with two specimens from Santa Monica Mountains (near Malibu, Calif.) that look very much like the cactus bee, *Diadasia australis*, but are likely a new undescribed species.

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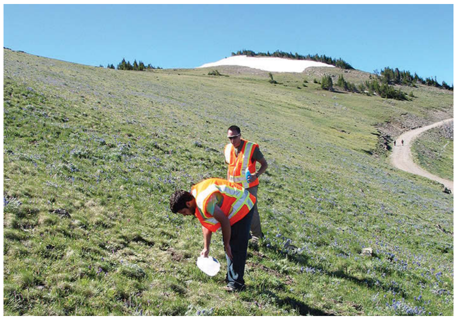

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Figure 6 (top). Arid dune pollinator habitat at Mojave National Preserve.

Figure 7. Interns set up a transect of bee bowls at a high-elevation meadow site at Yellowstone National Park.

Bumble bees are another group of bees of great conservation interest, as several species have shown precipitous declines in all or parts of their ranges during the last two decades. These hardy bees make up a large component of high-elevation and northern-latitude bee faunas, so as results come in from western mountain and Alaska parks, we hope to contribute important range information that will help us assess the status of bumble bees in these regions.

In the deep South, many rare and unusual discoveries are being made in Florida parks, including sand specialists, such as the metallic sweat bee *Augochloropsis anonyma* from Biscayne and Canaveral, and the rarely collected southeastern endemic, *Dianthidium floridiense*. Another exciting find at Canaveral was the polyester bee *Colletes titusensis*, named after the town nearest to Canaveral, Titusville (fig. 9). The last recorded specimen of this rare endemic was collected in 1938.

Next steps: Discerning patterns and making links to climate change

Once the 43,000+ bee records for all 46 parks are complete and ready for analysis, the resulting database will represent the largest replicated survey of native pollinators anywhere in the world. The study design allows analysis of bee diversity and distribution patterns at multiple scales. For instance, we can compare bee communities between vulnerable and common habitats within individual parks to determine whether vulnerable habitats have more rare and endemic species or are distinctive in other parameters (e.g., species richness, diversity, nesting guilds, proportions of floral specialists or parasitic bees). This already seems to be the case with coastal and lakeshore dune habitats, where we have found many dune specialists (see sidebar, next page).

We can also make these comparisons across regions to determine whether, for example, bee communities in coastal dune sites across the Atlantic coastal plain are more similar to each other than bee communities in paired vulnerable-common sites within parks are to each other. If so, this indicates a strong regional "dune signal" (versus a "park signal") and suggests that we can assess the threats of climate change to these more vulnerable habitats at a regional scale, and perhaps also develop regional management guidelines and conservation partnerships. Similarly, we will make these comparisons for dune

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versus inland communities on the Great Lakes and the Pacific coast, for sand-dominated areas versus other open habitats in southwestern deserts, for subalpine/alpine versus lower-elevation meadows in the western mountains and in subarctic regions of Alaska, and so on. Ordination and regression analyses will help us decipher what the dominant environmental (e.g., elevation, latitude, aspect, soil type) and climatic (e.g., mean air temperature, precipitation) drivers are for any patterns we see within and across habitats.

We are developing climate summaries for each sampling location that compare historical and current conditions with future predictions from the latest downscaled climate models. Climate changes are already evident, but the change is not uniform across the country. Rates of change in temperature and precipitation patterns, especially the timing during the growing season, will likely have profound effects on the future makeup of a park's native bee populations. With these climate data we can begin to make predictions about the fate of bee communities. By examining species distributions across the environmental and climatic gradients surveyed, we can comment on the likelihood that a particular species will persist under new regimes of these gradients, such as a new combination of mean temperature and different soil type. Predictions for individual species can be combined and scaled up into estimates of effects of climate change on entire bee communities.

Long-term monitoring of bee communities from sensitive and common habitats in any of the 46 parks will also be possible now that we have established a baseline against which we can measure change. The sampling protocols are simple to repeat and can be replicated in many other habitats of interest. Monitoring to assess the trajectories of bee abundance, richness, and other parameters in climate-sensitive habitats may be especially informative on a regional scale.

Catching the buzz: Getting the word out about bees

Another key objective of the project was to educate park staff, volunteers, and visitors about the remarkable diversity and ecological importance of native bees, as well as their potential vulnerabilities to climate change. We encouraged parks to actively engage interns, volunteers, and citizen science groups by recruiting them to run the sampling transects. For example, a group of Virginia Master Naturalists ran samples at George Washington Birthplace (Va.), while Santa Monica Mountains and Channel Islands (Calif.) combined forces to train students from two local colleges and an after-school youth leadership program to collect their bees. Student Conservation Association and Youth Conservation Corps volunteers sampled bees from high-elevation meadows in Yellowstone (Wyo.). Great Basin (Nev.) cleverly timed some of its bee sampling to coincide with its Hymenoptera bioblitz. It is clear that more than a few office-bound permanent NPS staff saw bee sampling as an ideal opportunity to escape their offices for a pleasant sunny day in habitats abuzz with flowers and bees. Who can blame them?

Each participating park will receive a summary of the bee data collected at its site in the form of a two-page resource brief, and species data will be available digitally through the Inventory and Monitoring Program's NPSpecies database. The resource brief will include a description of the sampling methods and a map of the transect locations (for future reference), a graphical comparison of the species found in common and vulnerable sites, a discussion of significant finds, contrasts, predicted risks to bees in vulnerable habitats with climate change, and suggestions for management actions or conservation concerns if warranted. These may include maintaining or restoring host plants for bee specialists or ensuring the availability of suitable nesting sites. The briefs will provide an effective way to share information about the project with administrators, resource managers, scientists, interpreters, and visitors. We will also prepare regional resource briefs to summarize findings in vulnerable habitats across regions and to suggest regional management guidelines.

We want to provide parks with engaging interpretive tools. For example, we can know a lot about bees, appreciate them as pollinators, and feel concern for their well-being in the face of environmental threats, but it is difficult to truly connect with an organism you can't see very well. Perhaps one can fall for the charm of a bumble bee, but most bees are just too small to admire aesthetically. Sam Droege and colleagues have been working hard to overcome this problem with a cost-effective camera setup for putting even the tiniest sand-dwelling *Perdita* bees in a highly magnified spotlight (bottom photo, page 88). Several hundred images of bees collected in national parks, demonstrating a magnificent diversity of form, color, texture, and pelage, are available for any type of educational use at www.flickr.com/photos/usgsbiml/sets/72157630468656672 (with many additional western species in the photographic queue).

Another (free) resource for fostering an appreciation for the diversity of bee bodies, natural history, ecology, and behavior is Bee Observer Cards, which were developed collaboratively by the Encyclopedia of Life and the Farrell Lab at Harvard University. Much of this work was funded by the National Park Service for this bee project, and all participating parks will receive hard-copy decks of the cards, which can also be downloaded electronically from eol.org/info/498.

In the end, among the most significant outcomes of this ambitious project will be the simplest: an awareness that native bees deserve attention in our national parks, and a realization that there are important discoveries to be made in almost any habitat we choose to investigate. Many parks have already engaged in new bee-focused activities as a result of their participation in the project. For example, at Fire Island (N.Y.), interpretive programs highlighting native bee diversity are planned at the William Floyd Estate this season; at Organ Pipe Cactus (Ariz.), new sampling transects were set up to document the bee fauna associated with an endangered acuña cactus; and at Isle Royale (Mich.), a college intern was recruited to extend its collections and photograph bees. Says Paul Brown, chief of natural resources at Isle Royale, "Prior to the study we knew of only a handful of bee species on the island . . . now we are aware of over 60 species." We hope the success and relevance of this work will inspire even more parks to catch the buzz.

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Reference

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