

BREAKTHROUGHS

UC BERKELEY COLLEGE OF NATURAL RESOURCES • SPRING 2019

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INSECT AWE

Elizabeth Cash, a member of professor Neil Tsutsui's lab, teaches Bay Area Science Festival attendees about the diversity of ants in California. Read more about the lab's outreach and citizen science efforts on page 14.

PHOTO: Lawrence Luk



THE POWER OF
PARTICIPATION
Spotlight on Citizen Science



Whenever I'm out hiking, I like to log on to the iNaturalist app to create a record of some of the notable flora or fauna I've observed. From a delicate deer mushroom in Tilden Park to the dew-covered live oak leaves in Pepperwood Preserve, it's all there, captured and shared with a global community of scientists and naturalists at the tap of a few icons. My entries have become a natural history diary of my life outdoors. A few years ago, I worked with an undergraduate student on a project using iNaturalist records, and among the observations we pulled was one of my own uploads from a weekend hike. We published a paper on the study in 2015. Talk about full-circle citizen science!

Citizen science has emerged over the past two decades as an increasingly popular approach for researchers in many fields. Mobilizing networks of nonscientist observers makes it possible to obtain data faster, in larger quantities, and from locations that weren't accessible before—and along with the data gathering come educational and outreach opportunities.

During my first year as dean, I've been excited to learn about numerous citizen science endeavors taking place in the College. This issue of *Breakthroughs* highlights many of these partnerships between CNR scientists and the volunteers who help them assemble powerful data sets for projects related to conservation biology, phenology, forest health, human-wildlife conflict, and more. Some of the projects utilize technology, and others rely simply on paper and pencil, but all share the goals of advancing research and creating connections between the scientific community and the public.

We hope you'll enjoy reading about these collaborations and even consider getting involved yourself.

I welcome your feedback at dackerly@berkeley.edu.

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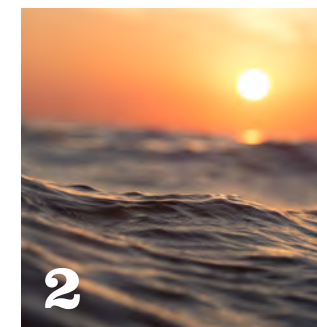
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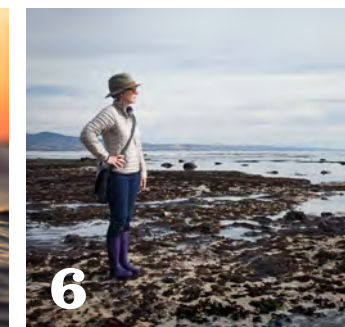
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ONLINE

Be a Citizen Scientist
Visit scistarter.com to search for a citizen science research project or event near you.

COVER: Illustration by Maya Edelman

PHOTO: Shayne Estill



PHOTO: William Suckow

Co-author Laura Sims examines *Phytophthora*-infected coffeeberry plants at a restoration site.

Invisible Pathogens Endanger Ecological Restoration

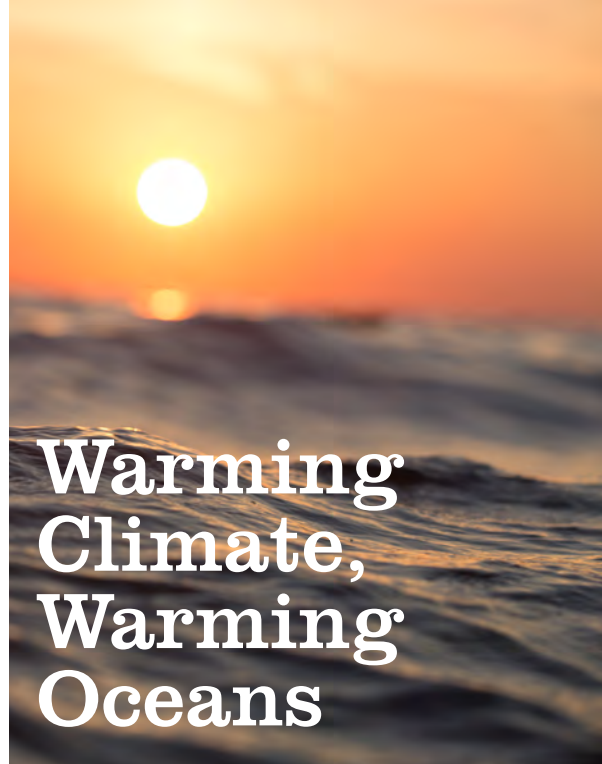
In 2014, the California Department of Food and Agriculture reported an alarming discovery: native wildflowers and herbs grown in nurseries and then planted in ecological-restoration sites around California were infected with *Phytophthora tentaculata*, an exotic plant pathogen that causes root and stem rot.

The presence of this pathogen in restoration sites raised the frightening possibility that ecological restoration, rather than returning disturbed sites to their natural state, may actually be introducing deadly plant pathogens into the wild. New work by a team of scientists in the College of Natural Resources shows just how widespread and harmful the threat of pathogens from restoration nurseries may be.

Led by **Matteo Garbelotto**, a Cooperative Extension specialist and adjunct professor in the Department of Environmental Science, Policy, and Management, the team surveyed native-plant nurseries in Northern California and found that many harbored *Phytophthora* pathogens. What's more, strains of the pathogens from the native-plant nurseries were shown to be at times more aggressive than strains found in the wild, and some of them are rapidly developing resistance to the fungicides that can be used to control them, the researchers found. Results from the team's work on this topic appeared last December in *PLOS One*, *Plant Pathology*, and *California Agriculture*.

Working with restoration nurseries around the state, the team helped implement new management practices to try to limit the spread of disease without using fungicides. These guidelines, which include careful management of water runoff and soil to avoid cross contamination, reduced the prevalence of disease to nearly zero a year after implementation. — KARA MANKE

For more on Garbelotto's research and work with citizen scientists in California, see page 12.



Warming Climate, Warming Oceans

Heat trapped by greenhouse gases is raising ocean temperatures faster than previously thought, concludes an analysis of four recent ocean-heating research studies. The results provide further evidence that earlier claims of a slowdown or hiatus in global warming over the past 15 years were unfounded.

"If you want to see where global warming is happening, look in our oceans," said **Zeke Hausfather**, a graduate student in the Energy and Resources Group (ERG) and a co-author of the analysis. "Ocean heating is a very important indicator of climate change, and we have robust evidence that oceans are warming more rapidly than we thought."

Ocean heating is a critical marker of climate change because an estimated 93 percent of the excess solar energy trapped by greenhouse gases accumulates in the world's oceans. And unlike surface temperatures, ocean temperatures are not affected by year-to-year variations caused by climate events like El Niño or volcanic eruptions.

The analysis, published in January in *Science*, shows that trends in ocean temperature match those predicted by leading climate change models, and that overall ocean warming is accelerating.

The climate change models—assuming a "business as usual" scenario in which no effort is made to reduce greenhouse gas emissions—predict that the temperature of the top 2,000 meters of the world's oceans will rise by 0.78 degrees Celsius by the end of the century. The thermal expansion caused by this bump in temperature will raise sea levels by 30 centimeters, or around 12 inches, on top of the sea level rise already caused by melting glaciers and ice sheets. Warmer oceans also contribute to stronger storms, hurricanes, and extreme precipitation.

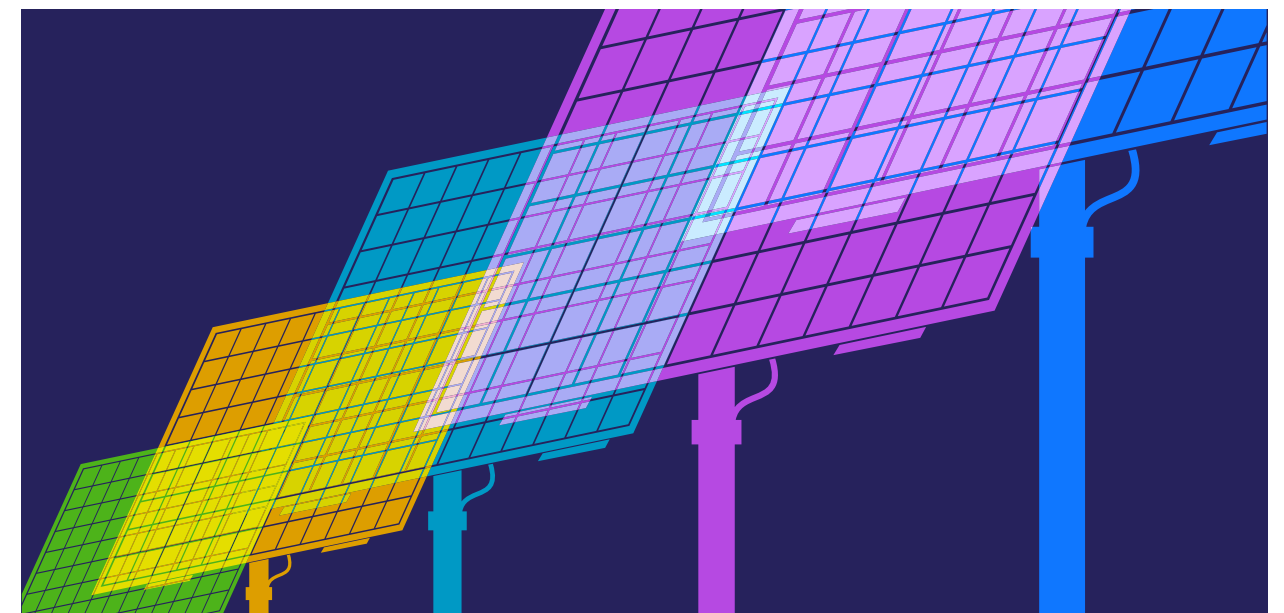
— KARA MANKE

Wolf Prize Goes to David Zilberman

David Zilberman, a professor in the Department of Agricultural and Resource Economics, has been awarded the 2019 Wolf Prize in Agriculture. The Wolf Prize is an international award granted by the Wolf Foundation in six categories; the prize Zilberman received is often referred to as the equivalent of a Nobel in agriculture. Zilberman was honored in recognition of his work developing economic models for fundamental problems in agriculture, economics, and policy.



PHOTO: Elena Zhukova



Inequalities in Solar Energy Access

By combining remote sensing data from Google's Project Sunroof with census tract information, CNR researchers have discovered significant racial disparities in the adoption of rooftop solar photovoltaic systems in the United States. Their findings were published in January in *Nature Sustainability*.

"Our work illustrates that while solar can be a powerful tool for climate protection and social equity, biases and barriers to access can dramatically weaken the social benefit," said co-author and ERG professor **Dan Kammen**.

The researchers found that among households with the same median income, black- and Hispanic-majority census tracts had fewer rooftop solar arrays installed than areas with no majority ethnic group, by 69 and 30 percent, respectively.

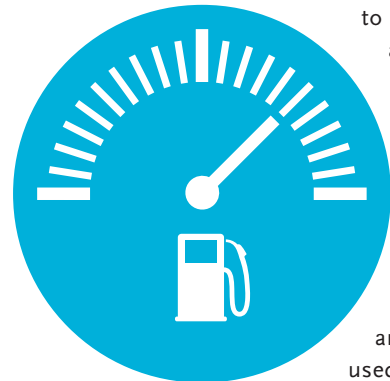
White-majority census tracts had 21 percent more rooftop solar arrays installed.

When correcting for homeownership, black- and Hispanic-majority census tracts had fewer rooftop solar arrays installed by 61 and 45 percent, respectively, compared with no-majority tracts, while white-majority census tracts had 37 percent more arrays installed.

"Advances in remote sensing and in 'big data' science have allowed us to chart who gets to benefit from the solar energy revolution and, therefore, to think more deeply about the effectiveness of current policies and approaches to accelerate solar photovoltaic deployment," said **Sergio Castellanos**, an ERG postdoctoral scholar and co-author on the study.

When Policy Numbers Don't Add Up

When it comes to fuel economy standards, there is no single accepted procedure for arriving at the miles-per-gallon targets that automakers must hit. Rather, analysts use any of multiple parameters and tactics to calculate the potential economic and environmental impacts of fuel efficiency levels.



So when **James Sallee**, an assistant professor of agricultural and resource economics, first saw that the Obama-era standards had flunked the current administration's 2018 cost-benefit analysis—which was subsequently used as justification for rolling back the stricter standards—he didn't think much of it. Analysts had correctly referenced some of his published research findings, and they were working with an ambiguous process.

After digging into the analysis further, however, Sallee went on to co-write, with 10 academic colleagues, a commentary in *Science* that raises serious questions about the scientific validity of the proposed rule change. That's because the

Environmental Protection Agency and the National Highway Traffic Safety Administration—the agencies that govern fuel standards—arrived at a completely different conclusion from their predecessors' using exactly the same data.

"So we wanted to know, what's the difference?" Sallee said. "When we dove into how they changed the model, we disagreed with almost all of the ways the major changes were implemented." The team uncovered mistakes in math and in the application of economic theory.

Because of errors like those as well as other actions—such as the abandonment of the Paris Agreement and the Clean Power Plan—Sallee noted, scientists are increasingly concerned about a perceived sidelining of science in the Trump administration's decision-making processes. "It's unambiguously distressing. In the long run, that's the biggest concern, rather than any individual policy."

Sallee said that the real litmus test will be whether federal analysts address the errors. If they don't, he added, the *Science* article forms part of a "trail of concern"—formal scientific objections that could potentially be used by future leadership to revoke the current policy decisions.

— ANN BRODY GUY

\$9.2 Million to Tackle Liver Disease

A research team co-led by **Anders Näär**, a professor in the Department of Nutritional Sciences and Toxicology, has received \$9.2 million from the Novo Nordisk Foundation to research new treatment therapies for nonalcoholic steatohepatitis (NASH).

NASH is a progressive subtype of nonalcoholic fatty liver disease, which is the most common type of chronic liver disease worldwide. While the cause of NASH is unknown, the disease is associated with obesity and metabolic syndrome and can progress to liver failure and hepatocellular carcinoma.

Näär's team will study microRNAs—snippets of noncoding RNAs that can act as crucial regulators of human physiology and disease—to develop microRNA-targeted drugs for NASH.



PHOTO: Natalea Schagger

IN THEIR OWN WORDS

By Meredith Fowlie



Private Pollution Monitors: Gimmick or Game Changer?

State and federal government agencies have traditionally been the primary source of air quality data, but the high cost of monitoring has limited the scope of publicly available information. In the United States there are fewer than 1,000 regulatory-grade compliance monitors measuring PM_{2.5}—the very small particles that pose significant health risks.

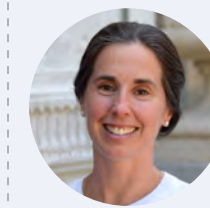
There can be big differences in the levels of pernicious local pollutants like PM_{2.5} over short distances, so the sparseness of this monitoring network really matters for anyone looking to understand or limit their exposure. Recently, though, low-cost, consumer-grade sensors from companies like PurpleAir have started to fill some big information gaps.

Here in California, private citizens have deployed more than three times as many air pollution sensors as the government agencies charged with monitoring our air quality. Although the technology is not as reliable as regulatory-grade monitors, our colleagues at the Lawrence Berkeley National Laboratory have found that it works surprisingly well. And once connected to Wi-Fi, privately owned PurpleAir devices link up with a global network that displays their data on a map in real time for all to see. This crowdsourcing of air quality information marks an important shift away from the status quo and opens the door for citizen scientists who want to know more about the air they breathe.

During the Camp Fire in November 2018, Northern California was clouded with smoke for over a week. Outdoor particulate

concentrations reached dangerous levels. Using real-time feedback from our PurpleAir monitor, my family and I started experimenting with adaptation. This little sensor made invisible air pollution visible to us, and we were able to identify and make adjustments—like replacing our furnace filters and constantly running the fan—that measurably improved our indoor air quality.

A 2017 California law, AB 617, mandates that community-level air monitoring be put in place by mid-2019 to improve conditions in communities that are disproportionately affected by outdoor air pollution. To keep implementation costs manageable, low-cost sensors will likely play an important role. These monitors aren't a perfect substitute for regulatory-grade ones, but they could be important complements. If well-crafted policy implementation and community mobilization can catch up with innovations in sensor technology, these cool gadgets could become a real game changer.



Meredith Fowlie is an associate professor in the Department of Agricultural and Resource Economics. A longer version of this article originally appeared on the blog of the Energy Institute at the UC Berkeley Haas School of Business.

What Counts

By Mary Ellen Hannibal



The author (foreground, with brown hat) and other volunteers gather at a tide pool in Half Moon Bay, California to count sea stars as part of a citizen science project facilitated by the California Academy of Sciences.

PHOTO: Liam O'Brien

Citizen science enables observation at the scale of ecological change

Mary Ellen Hannibal is a science journalist, author, and dedicated citizen scientist. Her recent book, *Citizen Scientist: Searching for Heroes and Hope in an Age of Extinction*, was named a best book of the year by the *San Francisco Chronicle*. Her writing has been featured in dozens of newspapers and magazines, including *Science*, the *New York Times*, and *Bay Nature*.

If Charles Darwin had carried a smartphone equipped with iNaturalist in 1835, he would have instantly sent ornithologist John Gould photographs of finches from the Galápagos Islands. Gould wouldn't have had to wonder which island each bird was from because Darwin had neglected the very detail—geography—that would become a cornerstone of his theory of evolution by way of natural selection. The iNaturalist app would have assigned each photograph the date, time, latitude, and longitude of its occurrence. Gould would have seen precisely where the birds were from—though of course he would have wanted to study the physical specimens as well.

Darwin makes a good reference point for today's citizen science. The term generally refers to nonscientists contributing to scientific research, but the practice is as old as the human need to understand our environment in order to survive in it. With

no advanced degree, Darwin was an impassioned amateur. He performed some experiments, but most of his discovery was based on direct observation and pattern recognition—the essence of modern citizen science, which is turbocharged by smartphone technology and massive computing power. Aboard the *Beagle*, Darwin was in service to British colonial ambitions. Necessitated by the biodiversity crisis, today's citizen science is more in the spirit of Aldo Leopold. In *A Sand County Almanac*, Leopold wrote that the individual should interact with the environment in an ecological rather than sovereign way: as a “plain member and citizen” of the land. The way to do that is to observe as Darwin did. Today, the data gathered by citizen scientists follows his template for understanding life on Earth.

In the decades following the 1859 publication of *On the Origin of Species*, the world of science energetically set out to collect examples of life

and to attempt to affix each species in its place on the tree of life. Amateur collectors were fundamental to this enterprise. Sugarcane heiress and citizen scientist exemplar Annie Alexander organized and funded bone-seeking expeditions to aid the creation of an accurate picture of the past. A thinker as well as a collector, she helped found UC Berkeley's Department of Paleontology, Museum of Paleontology, and Museum of Vertebrate Zoology (MVZ). Building on Darwin's proposal that life proceeds by modification through descent, Alexander realized that to understand fossils, it helps to understand their closest living relatives—perhaps she took that into account when posting Joseph Grinnell at the helm of the MVZ. Among other notable undertakings, Grinnell refined the methodology by which instances of life were observed and collected, placing the utility of his work in future terms. He could already see land-use change impacting biodiversity and hoped that his now-famous 1914–20 biotic survey would, a century later, provide “the original record of faunal conditions in California.” And researchers have, indeed, compared contemporary and historical conditions by referencing Grinnell.

Less than 100 years later, we have, out of necessity, turned from focusing on how life began to figuring out how to keep it from disappearing. Rather than collecting physical specimens, we more often capture digital representations of their occurrences. The basic template of the survey and the resurvey of

Citizen science connects the local to the regional and the global.

who exactly is living where, and when, provides a road map of change over time and helps illustrate Darwin's idea of unfolding life. While scientists still inventory and monitor biodiversity themselves, many also now recognize the utility of engaging volunteers in the collection, and even the analysis, of data. Today, all over the world, people are doing “bioblitzes” to document the natural world. The data collected is supported by GPS and the atomic clock. It's aggregated in databases that make it possible to query how temperature and precipitation patterns track alongside species observations. Grinnell, refiner of the ecological niche concept, would be enthusiastic about the possibilities, which include analyzing the current and future impacts of climate change.

Those impacts are far-reaching, swift-moving, and alarming. Projections reference global models built with satellite data, but ecological adaptations occur at local levels. How to build data sets that reconcile field measurements like those taken by Grinnell with remotely sensed imagery of continents and oceans?

When people make direct observations of nature, they don't just take a photograph; they make a connection.

Enter the smartphone, GPS, and the citizen scientist. Citizen science has the potential to comprise a global biodiversity observation network made up primarily of human eyes. Every individual can contribute specific observations that aggregate into a data-rich big picture. While studies analyzing the accuracy of amateur observations are inconclusive, many citizen science platforms can provide a corrective function. At nearly 600 million avian observations and counting, eBird's numbers are so rich that they render misidentifications statistically insignificant. iNaturalist solicits expert opinion to vet every observation contributed to its site. When an observation is deemed "research grade," it is uploaded to the Global Biodiversity Information Facility, making it digitally available worldwide.

Citizen science enables observation on the scales at which nature actually operates. We are already seeing patterns that wouldn't be evident without its contributions. The sea star wasting syndrome affecting the intertidal from Alaska to Baja is one example: There aren't enough scientists to adequately monitor such a gigantic expanse, but hundreds of volunteers are helping document the loss, and, in some places, subsequent recruitment, of sea star populations. No single scientist or group of scientists could successfully take on the task of observing the "experiment" that global climate change is wreaking on the ocean ecosystem.

Greg Pauly, a herpetologist at the Natural History Museum of Los Angeles County, relies on volunteers using iNaturalist to populate his Reptiles and Amphibians of Southern California inventory and monitoring program. On his own, he would never have been able to collect the data he's accumulated, because the observations are largely on private property. He praises the project's participants for documenting elusive biotic interactions. "I've never seen alligator lizards mating with my own eyes," he says, "but I've seen more photographs of it than anyone else in the world." Pauly thinks that citizen science is revealing so much more about



Author Mary Ellen Hannibal has participated in numerous citizen science projects since 2011.

PHOTO: Richard Morgenstein

biology than we previously had access to that it will revolutionize our understanding of how life works.

And there's more to citizen science than science. When people make direct observations of nature, they don't just take a photograph; they make a connection. Among the very people collecting the data are the activists who organize to address detrimental change. We wouldn't even know that we are currently witnessing the crash of the monarch butterfly's migration on the West Coast, for example, if it weren't for the citizen scientists who have been monitoring the butterfly's numbers for 30 years. And those documenters are the foundation of efforts to support the monarch, which begin with disseminating the news and letting people know what to do about the crisis (in broad strokes: better address pesticide and herbicide use, habitat conversion, and global warming).

Citizen science is often presented as primarily an educational tool, and the practice does align perfectly with STEM guidelines. But citizen science does more than educate. It makes nature observation possible on temporal and spatial scales that would otherwise be inaccessible, and it can even help reveal ecological interactions. It connects the local to the regional and the global. Darwin would have marveled. If we are to continue to observe, as he did, "endless forms most beautiful," we must do so with databases in mind and iNaturalist in hand. **31**



The COLLABORATIVE NET

College of Natural Resources researchers are working with citizen scientists to gather data around the Bay Area and across the globe

By Mackenzie Smith | Illustrations by Maya Edelman

The COLLABORATIVE NET



COUNTING CARNIVORES

Working with Environmental Science, Policy, and Management (ESPM) professors **Justin Brashares** and **Maggi Kelly**, PhD candidate **Christine Wilkinson** enlists the help of farmers and livestock herders to study human-carnivore conflict in Kenya's densely populated Great Rift Valley. Community members contribute to the research by marking the locations of carnivore sightings and livestock attacks on blank maps. Wilkinson and her Kenyan team have conducted these participatory mapping sessions with nearly 400 people living within two kilometers of Lake Nakuru National Park and Soysambu Conservancy—two areas that regularly experience human-carnivore conflict.

CITIZEN SCIENCE SAFARI

Also in the Brashares lab, ESPM PhD candidate **Kaitlyn Gaynor** is a lead scientist on WildCam Gorongosa, an online platform through which people around the world classify animals in camera-trap photographs from Mozambique's Gorongosa National Park. Data from these images have provided scientists with insights regarding the restoration of large-mammal populations as the park recovers from decades of armed conflict, while giving people the opportunity to take a virtual safari from their own home and learn about ongoing conservation efforts. Gaynor's collaborators at HHMI BioInteractive integrate WildCam into high school science curricula, so that students can help contribute data while testing their own hypotheses about wildlife ecology. Participation in that high school program has come full circle for **Ava Wu**, who is now a UC Berkeley undergraduate working as a research apprentice on Gaynor's project.



THERE'S AN APP FOR THAT

In her role as director of the Informatics and GIS Program in the UC Division of Agriculture and Natural Resources, **Maggi Kelly** has, with her collaborators, built numerous smartphone applications for community science purposes. The team's apps allow users to tag coyotes in urban environments, map aquatic invasive species, report suspected instances of crop-damaging rice plants, chart the movements of wild pigs, and more.



CRAWLING THROUGH THE ARCHIVES

Through a project called CalBug, the Essig Museum of Entomology is working with seven other California institutions that have major insect collections to digitize and geo-reference one million insects and spiders archived throughout the state. Volunteers contribute by examining online photos of specimens from the collections and then transcribing the tag information accompanying each insect. These records become digital specimen labels—tags that are used by scientists to study biogeographic patterns, the spread of invasive species, and responses to land-use, climate, and other environmental changes. Led by ESPM professors **Rosemary Gillespie** and **Kipling Will** and Essig Museum curator **Peter Oboyski**, PhD '11 ESPM, the Berkeley effort has added more than 300,000 specimens to the California Terrestrial Arthropod Database since 2010.



90 SPECIES AND COUNTING

ESPM professor **Gordon Frankie** partners with the Sonoma Ecology Center and Cittaslow to conduct an annual count of Sonoma's native bee populations. In 2010, the first Sonoma Bee Count yielded 32 bee-species observations from three sites. Local residents have continued this project for nine years, leading to a community-wide awareness of bees' essential role as pollinators within ecosystems. Using pan traps and doing aerial collections from flowers, the volunteers have to date found more than 90 species, which are identified by taxonomist **Jaime Pawelek**, BS '08 Conservation and Resource Studies, and then archived in UC Berkeley's Essig Museum of Entomology.



MUSHROOM MAPS

Tom Bruns, a professor in the Department of Plant and Microbial Biology, works with citizen scientists to survey mushroom species in Berkeley and beyond. Collaborating with local mushroom clubs, including the Bay Area Mycological Society and the Mycological Society of San Francisco, Bruns coordinated a survey of fungi in Point Reyes National Seashore from 2004 to 2007 and another such survey in Yosemite National Park from 2010 to 2012. These "mycoblitzes" resulted in online catalogs of fungi found in the parks. Building on this success, Bruns organized the first meeting of the North American Mycoflora Project, a space for professional and amateur mycologists to discuss survey techniques and share their knowledge of North American macrofungi. Now with other mycologists at the helm, the project has continued to mobilize mushroom clubs across the US and Canada to gather fungi data. Bruns has also deployed students and community members to document fungi on the UC Berkeley campus. A catalog of these mushroom sightings can be found on the iNaturalist website, with more than 140 fungal species observed to date.





LEADING THE CITIZEN SCIENCE CONTAGION

PHD '96 PLANT PATHOLOGY

MATTEO GARBELOTTO

By Mackenzie Smith | Photos by Jim Block

Each winter, **Matteo Garbelotto** creates an assembly line in his Mulford Hall lab. To compile hundreds of training kits for volunteers, Garbelotto's team of researchers and students gathers boxes of supplies: pencils, pads, and laminated cards featuring photos of trees infected with sudden oak death (SOD).

"We give volunteers everything they need to be successful citizen scientists," says Garbelotto, a Cooperative Extension specialist and adjunct professor in the Department of Environmental Science, Policy, and Management. "Using paper and pencil to record data in the field is more time-consuming for my lab to translate into data, but it's also more inclusive—kids, families, and elderly community members alike can participate in SOD Blitz."

The SOD Blitz kits are used to train nearly 1,000 Californians annually to identify the fungus-like tree disease that causes cankers on trunks, foliage dieback, and eventually the death of the infected plants. SOD has killed millions of trees in 14 coastal counties in Central and Northern California, destroying healthy forest ecosystems throughout the state. There is no cure, but if SOD is identified early, its spread can be managed through chemical treatments and the removal of diseased trees.

Scientists first discovered the pathogen that causes SOD, *Phytophthora ramorum*, in California in the 1990s. As reports of the disease became more frequent, Garbelotto began developing treatment strategies and tried to create an accurate

map of infected trees throughout the state, a task that proved nearly impossible. "Even if I had an infinite amount of funding and hired a top-notch research team to survey diseased trees, it just wouldn't work," he says. To prevent SOD from ravaging California's forests, Garbelotto needed the data that only local experts—and concerned community members—could provide.

Hunting for Healthy Forests

Forests have been a fixture of Garbelotto's life since childhood. He was born in Venice—a city spanning 118 islands and constructed almost entirely of wood—and later moved to the northern Italian village San Martino di Castrozza, where lumber plays an important cultural and economic role. For centuries, spruce trees co-owned by San Martino and communities in the nearby Fiemme Valley have been felled to make world-class stringed musical instruments, including those crafted by Antonio Stradivari. More than 300 years after the luthier's death, Stradivari-made instruments can fetch upwards of \$16 million at auction. "Growing up in this part of the world helped me understand the cultural and personal value of trees," Garbelotto says.

When he arrived at the University of Padua as an undergraduate student, Garbelotto began studying forestry. He was interested in the life cycles of trees, but learned that surveying them is challenging: "To see the full span of a tree's life, I would need to live hundreds of years, in some cases," he says. "But I still wanted to understand how we can keep our forests healthy." Garbelotto ended up combining forestry with his childhood love of mushroom hunting. "When I discovered that the microorganisms that live in forest ecosystems—including fungi—can make or break a tree's health, I knew that forest mycology would be the focal point of my work."

Citizen Science 2.0

Throughout Garbelotto's 25-plus years at UC Berkeley—first as an international exchange student, then as a graduate student, and now as a researcher—understanding forest health has remained at the core of his research. After a failed two-year attempt to recruit volunteers for a project that he now sees was too "top-down" in design, he began listening more closely to the communities he visited. "People are very connected to their trees," he says. "As SOD spread, there was a feeling of despair among many Californians." They wanted answers and treatment options; Garbelotto needed data and accurate outbreak maps. In 2007, he launched a new SOD-focused citizen science program, SOD Blitz, with these dual needs in mind. This time, the project was driven by locals who wanted to save their forests.

What began with five communities in Northern California—Big Sur, Berkeley, Carmel, Sonoma, and Woodside—has grown into a program spanning 25 areas across the state, including cities, towns, and Native American tribal lands. Garbelotto personally leads the mandatory annual volunteer trainings, and with each year of survey results, the data sets become more powerful and more accessible. He now shares SOD Blitz findings online as soon as they're collected, via a website called SODMAP, whose database has been viewed more than one million times.

Citizen scientists want answers and treatment options; Garbelotto needs data and accurate outbreak maps.

According to Garbelotto, SODMAP keeps the program robust and active. "If we didn't share the data, people wouldn't keep participating—they need access to this information in real time, or it won't be useful for locating and treating SOD-impacted areas." SODMAP Mobile, the smartphone app Garbelotto and his team developed in 2013, makes it even easier for users to access the database while searching for potential SOD outbreaks in their neighborhoods. When Garbelotto first launched SOD Blitz and sought funding from organizations like the National Science Foundation, he was told that educating the public was important, but that citizen scientist-collected data wouldn't be viable for publication in peer-reviewed journals.

Garbelotto disagreed—a stance supported by his research: a 2015 study in *Frontiers in Ecology and the Environment* demonstrated that data gathered from SOD Blitzes was just as powerful and accurate as the SOD maps created by professional researchers. "The analysis for our paper used seven years of SOD Blitz data and created a complex, predictive model for SOD—the best ever created for the disease," he says. The publication confirmed Garbelotto's belief that community science projects can create the "perfect partnership," providing large-scale data sets for researchers while also meeting a community's need to act.

Garbelotto continues to innovate. A new project launched in February trains professional arborists working with property owners to collect and prepare trunk samples for SOD testing. "This is a socially equitable way to share sampling costs between homeowners, researchers, and arborists, while also giving all parties access to lab results," he says. Garbelotto calls this project "citizen science 2.0": gathering the expertise and passion of local stakeholders, professionals, and scientists to help stomp out a deadly tree disease, while collecting data that benefits researchers and community members alike.



Doug Schmidt, Cameron Chee, and Matteo Garbelotto prepare kits for volunteers who will gather data on infected trees.

Social Insects

Neil Tsutsui's lab gets the public involved
in the scientific process

By Nate Seltenrich



The Rickshaw Stop is better known for hosting indie bands than ant researchers. Although tonight's headliner falls in the latter category, the San Francisco club is packed, rapt audience members crammed cross-legged on the dance floor or in tight rows of folding chairs. I snag one of the last spots. All eyes turn to the man onstage, a man whose T-shirt reads "Eat Bugs," a man who is clearly in his element.

Amid earnest expressions of amazement, surprise, and the occasional "Yuck!" or "Creepy!," **Neil Tsutsui** spends the next half hour describing the stranger points of ant social behavior, many of which have been illuminated

through his own research: ants fighting to the death, ants building global supercolonies, ants kidnapping other ants and raising the young as their own.

As he's wrapping up, Tsutsui, a professor of arthropod behavior in the Department of Environmental Science, Policy, and Management, has one final message: the next time ants invade your home, take a closer look before you rush to exterminate them. By the sound of the applause, the crowd takes his words to heart.

This is Tsutsui's first time at Nerd Nite SF, a monthly series with the charming slogan

"Be there and be square," but it's certainly not his first time talking ants with the public. He was a guest on a 2012 episode of the podcast *Radiolab* and has presented at many events, including Oakland's Ars Technica Live and the California Academy of Sciences' weekly NightLife—live ants in tow.

At such gatherings, he and other members of his lab, including postdoctoral researcher **Elizabeth Cash** and PhD candidate **Kelsey Scheckel**, perform "aggression assays," placing Argentine ants from different colonies in a petri dish and seeing what happens (spoiler: it's not pretty). To demonstrate how ants

use pheromones for navigation, they lay a trail of the chemicals through a maze on a sheet of paper and show viewers that the ants quickly follow it.

They also answer questions, most commonly "How do I get ants out of my home?" The answer, at least as a first step, is to wipe the trail the ants have been following with soap and water to remove the pheromones, says Cash, who studies the genetic basis of how Argentine ants—one of the world's most damaging invasive species—produce and perceive pheromones and other important chemical signals.

PHOTO: Elizabeth Cash

SPARKING WONDER

Tsutsui considers outreach not merely fun but also central to his life's work as a scientist and teacher. It's an impulse with origins extending all the way back to his childhood in Flagstaff, Arizona, where he grew up alongside an expanse of forest. He'd spend his days there roaming free, chasing lizards and insects and exploring whatever else intrigued him, returning home by sunset.

Tsutsui now lives in El Cerrito and has three kids of his own. He says his work with social insects, and that of others in his lab, continues to be motivated by "a raw curiosity about the world around us." Tsutsui and his 13 undergraduate, graduate, and postdoctoral researchers study ants and bees, in the lab and in the field, to better understand their behavior, communication, evolution, and relationship with the environment. This work has important real-world implications for conservation and pest control.

The lab's public engagement, meanwhile, is intended to spark a similar sense of wonder—particularly in those who have been "partitioned off from unstructured natural experiences" of the sort that led Tsutsui to decide at a young age to pursue entomology and, ultimately, to devote his career to learning more about why social insects do the things they do.

"Our main goal is to use insects as a vehicle for generating enthusiasm about the natural world," he says of the outreach. "Our hope is that once we engage people's interest, they will be more motivated to do some exploration on their own and hopefully support or participate in conservation efforts on their own."

MORE THAN SKIMMING THE SURFACE

There's yet another reason to engage the public, and that's to obtain scientific data from sources or in quantities that a single lab couldn't access on its own. Tsutsui and his colleague Brian Fisher, a curator of entomology at the California Academy of Sciences, started their first such project with the help of a National Science Foundation (NSF) grant in 2016.

Following the happenstance discovery of an abundance of ultrarare *Dracula* ants in a colleague's swimming pool, Tsutsui and Fisher wondered what else they could find. So they asked eager citizen scientists across California with access to a backyard swimming pool to commit to skimming the surface of the water once a month for bugs, then mailing the goods to the lab. "We wanted to engage people in nature, but we wanted to do it in a way that they'd become involved in the gathering of data," Fisher says. "To us, that's the most exciting part of science: the process."

Neil Tsutsui says his work is motivated by "a raw curiosity about the world around us."



Neil Tsutsui during a 2016 research trip in Mozambique's Gorongosa National Park. PHOTO: Roberto Keller-Pérez

Their ambitious project ended up including 11 sites and generating so much data that they're still picking through it—literally. By the time the one-year collection period concluded last summer, volunteers had amassed approximately 31,000 individual arthropods, all classified to the level of order, including 2,800 ant specimens, classified to genus.

A great number of those insects came from just one of the sites, a backyard swimming pool in forested Big Sur that was positively crawling with critters. It was skimmed each month by San Francisco nature photographer Julie Jaycox, a friend of the homeowner who says she volunteered after seeing a call for participants in *Bay Nature* magazine.

"I love 'playing in the dirt,' and this was about playing with bugs and water while also gathering info for someone who was interested in it," Jaycox says. Having recently read about the rapid decline in insect populations worldwide, she also saw value in contributing to Tsutsui and Fisher's project specifically.

Though her father was an entomologist who introduced his children to the study of insects when they were young, Jaycox had never before engaged in scientific research. But she took to it with aplomb. "If there were a lot of insects, it was about a three-hour job. I liked getting everything," she says. "But I cheated. I like bumblebees. If there were live bumblebees, I'd always rescue them."

After carefully cleaning the pool and the spa, then emptying the scupper and the vacuum, she'd dump the catch into a small tub containing about an inch and a half of alcohol for preservation. Then she'd drive this "big goey mess" back to San Francisco and personally deliver it to Fisher at Cal Academy.

Tsutsui and Fisher are now analyzing their data and looking for trends, like seasonal variations or geographic distributions. They've already made at least one important finding, which is that pools with Argentine ants tended to contain fewer native ants than pools without them.

"Argentine ants are such superior competitors that native ants can't coexist with them," Tsutsui says. And when the native ants disappear, other species can too, such as California's coastal horned lizards, which depend on native ant species to survive. For someone who's been studying Argentine ants for 20 years, the displacement of natives wasn't a huge surprise. But actually generating data that showed it—in our collective backyard, so to speak—was a testament to the power of citizen science.

"If you're going to do one of these projects, you have to be clear with yourself about your goals," Tsutsui says. There may be a trade-off between collecting the most rigorous data and ensuring ease of participation. "The pools project is a good example of that. It was labor-intensive for the participants, and it also resulted in high-quality data."





Elizabeth Cash showcases stick insects during the Bay Area Science Festival.
PHOTO: Lawrence Luk

“Insects are a vehicle for generating enthusiasm about the natural world.”

— Neil Tsutsui

On the other end of the spectrum is another experiment developed through the NSF grant, called ANT-Vasion, which is easier for more people to complete but less tightly controlled from a research standpoint. Participants test the ability of various household spices—turmeric, cinnamon, and others—to deter Argentine ants from reaching a bait. Anyone can download the instructions (and later submit results) at backyardbiodiversity.org.

Scheckel incorporates the experiment into a College of Natural Resources course for non-science majors called Insects and Human Society, which she helps teach as a graduate student instructor. “We actually have some interesting data that has come through,” she says. “It’s fun, and it’s something that people can put to use in their own homes.”

PASSION MAKES AN IMPRESSION

Scheckel and Cash both say they have long been keen to engage with the public as scientists—and are fortunate to have Tsutsui as their lab’s fearless leader. When Scheckel joined the lab as a first-year graduate student and started to grasp the role that citizen science could play in 21st-century conservation, it shifted the trajectory of her education and career. “I realized that I want to eventually move away from ‘hard science’ methodologies that take place tucked away in a lab and instead work out in the community, where I can interact with the public as an educator,” says Scheckel, who studies a species of kidnapper ant known to employ the young of other species as a captive workforce.

She now uses the smartphone app iNaturalist (a Cal Academy initiative originally developed as the master’s project of three graduate students at UC Berkeley’s School of Information in 2008) to access records identifying local populations of kidnapper ants. These records may be input by other researchers or by members of the general public and are available for anyone to view.

Unrelated to her dissertation, Scheckel and others in the lab also lead teams during citizen science “bioblitzes,” in which members of the public are



Kelsey Scheckel (also pictured left) and members of the Tsutsui lab during a research outing to UC Berkeley’s Sagehen Creek Field Station.
PHOTOS: Elizabeth Cash

invited to survey the biodiversity of a particular place during a 24-hour marathon, recording all observed species. Past events include the Save Mount Diablo Bioblitz and the Hopland Research and Extension Center Bioblitz. Scheckel further complements her academic pursuits by regularly participating in Cal Academy’s NightLife and volunteering at Bay Area school and community events organized by the nonprofit Community Resources for Science.

Engaging the public is not quite feasible in Cash’s work studying ant genetics from the lab bench. But she’s nonetheless dedicated to interpreting science and the natural world for nonexperts. “I tend to do outreach because I really enjoy sharing my passion about ant behavior and ant communication,” Cash says—especially when it comes to the notorious Argentine ant.

She and Tsutsui suspect that the insect’s success may be due in part to its pheromones—more specifically, a group of chemicals called cuticular hydrocarbons. “They’re basically waxes that these ants produce and then spread around on the surface of their exoskeleton,” Cash says. “[The ants are] coated in this waxy substance, and other ants use this blend of waxes to determine which social group the ant belongs to.”

Sensed through the antennae, these chemicals aid in communication and support a rich social structure. But Cash and Tsutsui hypothesize that the waxy coating might also be useful for preventing

desiccation in drier environments, helping Argentine ants invade a wide variety of habitats—and homes—all around the world.

The pheromone trails, aggression assays, and other crowd-pleasing demonstrations she does at outreach events are her way of communicating what could otherwise be a highly complex, rather dry foray into ant biology. At the same time, they reinvigorate her own interest in her work.

“I’m excited about connecting with people about my research,” says Cash, who led insect-focused nature hikes in the desert while pursuing her PhD in biology at Arizona State University. “I hope to spark an interest in someone else about insects and how fascinating they can be, and how important they are in our environment.”

From citizen science to social events, it’s all vital to Tsutsui, a scientist for whom public outreach is an art. In addition to his research, teaching, and public speaking, he’s even active on the city of El Cerrito’s Environmental Quality Committee, and he serves as a member of the East Bay Regional Park District’s citizens’ advisory group. His passion makes an impression, whatever the context. One afternoon as I sat writing this story and reflecting on Nerd Nite, a lone Argentine ant appeared out of nowhere on my keyboard. Instead of instinctively flicking it away, I remembered his appeal and bent down for a closer look.

Walking with Wildflowers

Gathering phenological data
on the Pacific Crest Trail By Tom Levy

PHOTO: Nicholas Kooyers

Thru-hikers on the 2,650-mile Pacific Crest Trail (PCT) are on a mission: walk from Mexico to Canada before snow hits the mountains in northern Washington. To accomplish this goal, hikers must travel 20-plus miles each day, a distance that doesn't always allow for stopping to admire high-country vistas or flora and fauna along the trail. But last summer, some of these long-distance hikers could be seen pausing, pulling out their smartphones, and recording information about the wildflowers scattered around their feet.

As participants in a citizen science project led by botanists **Benjamin Blackman** and **Nicholas Kooyers**, these hikers were gathering valuable data for the pilot of a multiyear National Science Foundation-funded study of flowering plants on the PCT. Their observations will help scientists understand how climate change may be altering plants' flowering and seed-making behavior, influencing, over generations, their DNA.

THE HIGHS AND LOWS OF DNA

Blackman, an assistant professor in the Department of Plant and Microbial Biology, has spent his career studying the genetics of how plant adaptation and domestication happen through time.

On the domestication side, Blackman's research focuses on sunflowers, a domesticated food crop known for its ability to track the sun's daily movement across the sky. "With domestication, changes in plant shape and physiology happen more quickly than in nature, perhaps in two thousand to ten thousand years," says Blackman. For sunflowers, domestication occurred over about four thousand to five thousand years, he says. "Domestication is a kind of human-made 'artificial selection,' highlighting really big changes that might take much longer in the natural world."

The yellow monkeyflower—*Erythranthe guttata*, also known as *Mimulus guttatus*—is the other subject of Blackman's research, his vehicle for examining plant adaptation as it occurs in the natural world. Thoroughly studied since the 1940s, the monkeyflower is considered a model plant for researchers working to understand how and why plant traits evolve in the wild.

Monkeyflowers can be found at many different elevations—from California's Central Valley to the high-elevation slopes along the PCT. And it turns out that the plants in these different locales have adaptive differences in their DNA, displaying traits that closely fit the needs governed by their diverse environments across elevations. The plants at snowy

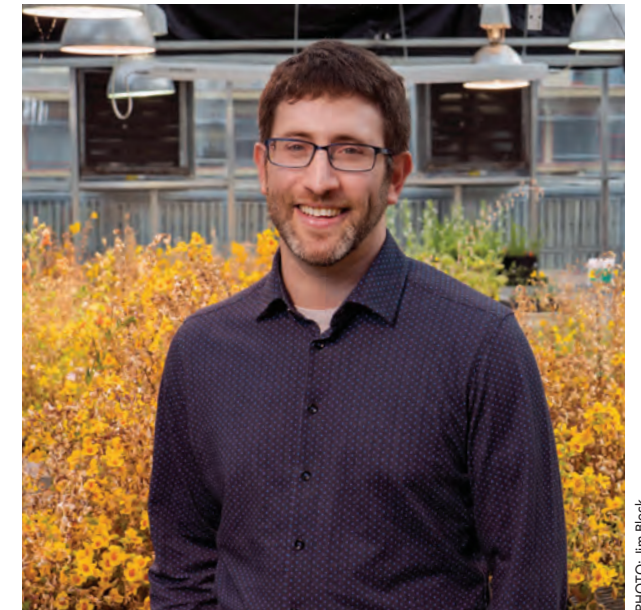


PHOTO: Jim Block

"The steady stream of long-distance hikers offers a wonderful opportunity for citizen science."

— Benjamin Blackman

high elevations contain DNA that signals for them to wait for longer, summertime days before they start producing buds and flowers. The DNA of the plants at lower elevations, meanwhile, allows them to start budding earlier in the year, when the days are shorter, so they can flower and set seed before the spring rains disappear and the summer heat dries up soil moisture. The life of a monkeyflower at a lower elevation today could offer a preview of what plants at higher elevations might soon face, since climate change will bring shorter spring seasons and longer, warmer, drier summers to all elevations. But how will those high-elevation plants—with their DNA telling them to wait for longer days before beginning to grow and flower—fare when the snowpack starts to melt earlier and the summer becomes hotter, even as the day length remains constant?

This is what Blackman's lab is working to understand. Using high-throughput genome-sequencing technology, the team looks closely at the DNA of monkeyflowers from various elevations to identify the adaptive genetic differences and provide insight into how the species may adapt as climates shift.

“We want to help visitors understand the basics of our research and the potential consequences of climate change.”

— Nicholas Kooyers

STOPPING TO SMELL THE FLOWERS

With the same goal of better understanding how changing environments will affect plant species, Blackman and Kooyers launched their citizen science project in the wild to monitor the monkeyflower and 19 other plant species at high elevations over multiple years. The involvement of hiker citizen scientists will allow the researchers to collect numerous observations of species at sites in two national parks and one national forest along the PCT each year, resulting in a powerful set of data that they could never obtain alone.

The idea to recruit backpacker volunteers first came to Kooyers in 2014, while he was conducting field research on monkeyflowers in Oregon as a postdoctoral researcher in Blackman’s lab. “I was thinking that to really get the kind of data we need, we’d have to survey plant populations on a daily or weekly basis, which isn’t realistic in remote locations,” says Kooyers. “While talking with my backpacker friends—who are extremely passionate about conservation—it struck me that a citizen science project could be the perfect coincidence of motivations.”

“The PCT offers a wonderful opportunity for citizen science, because there’s a steady stream of hikers along the trail throughout the growing season,” says Blackman. “Over time, we hope to crowdsource information about when plants are growing, how that’s changing, and if these changes are correlated with temperature or precipitation.”

To launch their Walking with Wildflowers project in 2018, Blackman and Kooyers partnered with the USA National Phenology Network, which has an extensive database of plant life cycle observations—known as phenology—collected by citizen naturalists nationwide. The database now holds more than 15 million observations from nearly 14,000 amateur naturalists, freely available to scientists, public decision-makers, and natural



From left: Jack Colicchio, Shayne Estill, and Nicholas Kooyers stop for a selfie while scouting observation sites for Walking with Wildflowers in Yosemite National Park.

resource managers. The network’s smartphone app, Nature’s Notebook, allows Walking with Wildflowers hikers to record observations along the trail.

Kooyers and Blackman collaborated with national park and forest service staff members to choose two segments of the PCT for the project. They included one stretch of trail in the southernmost portion of Washington State’s North Cascades National Park and another that starts in Inyo National Forest and continues north into Yosemite National Park. Each of the 15 data-collection sites they selected is home to a subset of the 20 plant species that hikers can observe, including lodgepole pine, yarrow, and, of course, monkeyflower.

While many of the sites are in remote areas, Blackman and Kooyers also intentionally included sites accessible to day hikers. At these, they expect to get many more observations than farther out on the PCT. One of the sites in Yosemite isn’t even on the PCT; it’s near a ranger station that sees heavy foot traffic. “The goal with that site is primarily educational,” says Kooyers. “We want to help visitors understand the basics of our research and the potential consequences of climate change on these plants’ life cycles.”

A site like this, where it’s possible to gather observations from many hikers in one day, is also handy for verifying data reliability. Great variation in a day’s data might point to hikers struggling to make consistent observations. It could also indicate that data collected at other sites is not as trustworthy as researchers would like.



Undergraduate student Estill pollinates monkeyflowers in a greenhouse on the UC Berkeley campus. PHOTO: Jim Block

During the pilot summer last year, two test hikers from Blackman’s lab, **Jack Colicchio** and **Shayne Estill**, helped evaluate site choices and fine-tune plant-location instructions. They also discussed the program with passing hikers to recruit volunteers and posted flyers on ranger station bulletin boards.

Estill—an undergrad lab assistant who is majoring in molecular and cell biology—completed her first-ever backpacking trip while assisting at the Yosemite and Inyo sites. The trail time helped her solidify her academic goals. “I learned that climate change affects even the smallest organisms,” she says. “Thinking like a researcher has been fun, and this experience encouraged me to continue training to become a scientist.”

Kooyers stresses that sites need to be easy to find, so they’re preferably near a recognizable landmark like a water crossing or a trail signpost. One known as the “lightning spire,” in the North Cascades, is hard to miss; it’s near a 25-foot tree struck dead by lightning.

To find the sites, hikers reference Walking with Wildflowers companion guides that contain maps of each segment, GPS coordinates and photographs of each site, and pictures showing the plants included in the study. Once they locate a site, they look for small metal tags placed at ground level, which identify each plant flagged for the project. From there, the Nature’s Notebook app asks simple questions that guide observers: Does the plant have buds, leaves, or flowers? If yes, how many flowers, how many buds? And so on. These questions help create accurate portraits of a site during each observation.

WALKING INTO THE FUTURE

Even with minimal advertising during the pilot year, 38 hikers participated. They uploaded approximately 2,500 separate plant observations, nearly 1,500 from North Cascades National Park and almost 1,000 from Inyo National Forest and Yosemite National Park.

The Walking with Wildflowers team is analyzing this first-year data set, and Blackman and Kooyers are hoping for many more hikers and observations this summer. Their goal is one hiker checking plants at least once every one to three days at each site. Hiker participants can directly access all the study data through the USA National Phenology Network’s website. And, notes Kooyers, who is now an assistant professor at the University of Louisiana at Lafayette, volunteers will eventually receive research progress updates via a listserv.

Blackman says he once imagined “traipsing around doing research in the mountains or foothills” and then felt the dream come true while he was a postdoc on a three-week trip collecting plant specimens in the Sierra and Cascades. That feeling, he says, has resurfaced with the Walking with Wildflowers project. “I’m doing the exact fantasy project I pictured when I was an undergrad,” he says. “And it’s so exciting to be able to involve a group of citizen scientists in collecting valuable data for the scientific community on the biological impacts of climate change.” **311**

For more details or to get involved in Walking with Wildflowers, visit pct.usanpn.org.

Q&A

When Science Is Social

By Julie Gipple



Heidi Ballard, PhD '04 Environmental Science, Policy, and Management (ESPM), completed her doctorate—having previously earned degrees in biology, curriculum development, and teaching—with perfect timing. Passionate about sustainable development and collaborative research throughout her studies, she witnessed the advent of what we now call citizen science—and became a defining voice in the field. *Breakthroughs* sat down with Ballard to discuss the opportunities and outcomes of public participation in scientific research.

What was your path to where you are today, and when did you first become involved with community and citizen science?

During my years in higher education, I became fascinated with ethnobotany—the study of cultural uses of plants—as well as the emerging fields of conservation biology and sustainable development. Across all these fields, I was most drawn to studies that involved collaborative monitoring, where different groups of stakeholders—environmentalists, resource-dependent communities, scientists, and agencies—all came together to collect data.

When I set out to focus my dissertation on non-timber forest products in the Pacific Northwest, I found it odd that no one managing the forest was talking to the people who were actually doing the harvesting. Luckily, ESPM professor **Louise Fortmann** introduced me to the concept of participatory action research. She showed me that there's a whole world of respectful and collaborative research partnerships between scientists and community groups. My world expanded further thanks to my advisor, ESPM professor **Lynn Huntsinger**, who knew how to collaborate with ranchers working “on the ground” as well as with federal agencies, and ESPM professor **Nancy Lee Peluso**, who introduced me to political ecology. I also learned a lot in a School of Public Health course on community-based participatory research taught by **Meredith Minkler**. I ended up using all these methods and conducting my dissertation research with Latino immigrant harvesters, to understand their methods for gathering shrubs from the forests—after originally being told that “they won't talk to you.”



Heidi Ballard notes that citizen science projects can help participants view science as a social, collective venture to which they can contribute.

PHOTO: Eva Guralnick

“Participants remember that a scientist is depending on their data, so they dig in and make sure the methods are right.”



Participants in the Pacific Grove Museum of Natural History California Naturalist course collect data on coastal ecosystems during their class citizen science project.

PHOTO: Courtesy of the PGMNH

After graduate school, I was able to combine my interest in involving the public in scientific research with my love for curriculum development and my background in teaching high school when I joined the faculty at the UC Davis School of Education in 2006. It was a perfect fit.

That same year, I went to the annual meeting of the Ecological Society of America and heard a lot of buzz about this thing called citizen science. I joined the conversation, and it all evolved from there!

Public participation in scientific research has increased exponentially since then. How and why has this happened?

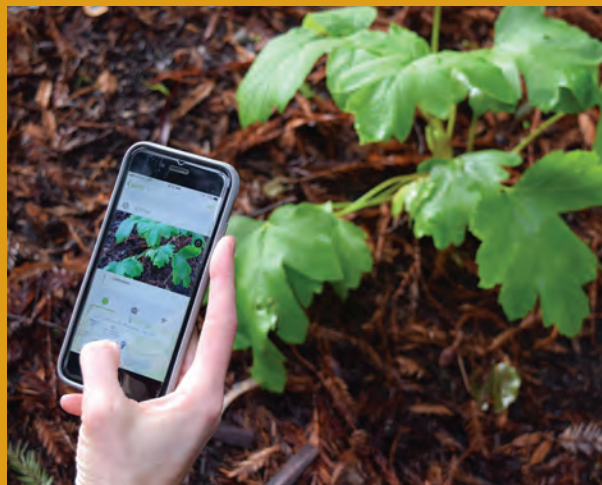
First, technology and the internet. The fact that people can enter data into an online platform instead of mailing in a paper list of birds they saw, for instance, has created so many possibilities for research. The prevalence of mobile phones that capture high-quality photos, which are time-stamped

and geolocated, then uploaded through an app within seconds—all this has revolutionized what people can contribute from virtually wherever they are, about almost anything.

Beyond technology, there's also a growing awareness of social justice issues and a feeling that we need to democratize science. Around the globe, people are realizing that everybody can engage in and improve the larger endeavor of science, which can then inform decision-making as we tackle global challenges like climate change and a rapid loss of biodiversity.

Tell us about your work as a professor of environmental science education.

I study what and how people learn through participation in community and citizen science projects. Lately, my research has looked at how projects in schools or after-school groups can be designed to not only help kids learn about environ-



Smartphones and apps like iNaturalist and eBird have resulted in a dramatic increase in citizen science projects worldwide.

PHOTO: Natalea Schager

mental science but also give them a sense of agency around going out to make positive impacts in their communities and beyond. I also teach courses that show students from many disciplines—including ecologists, linguists, plant scientists, and even musicologists—how participatory research methods can help them do better and more equitable research.

What have you discovered about citizen science's role as an educational tool?

One goal can be to help kids learn about science and to create a pipeline for tomorrow's scientists, but there's so much more than that. We can also hope that participants of all ages understand the natural world better and use the scientific process in their everyday decisions. We have found that there can be an identity shift—people begin to see themselves as part of the scientific community and to view science as a social, collective venture to which they can contribute. And then, ideally, they care more about advocating for and conserving the environments they're studying.

You're the founder and faculty director of UC Davis's Center for Community and Citizen Science, which is the first endeavor of its kind. What's the center all about?

As hubs of both education and research, universities are the ideal place to enhance great research and make it more equitable. I wanted a center on campus to help institutionalize public participation in science research and provide a resource to help community and citizen science projects here at UC Davis—and across the world—be more strategic and effective for both research and educational outcomes. To that end, we offer workshops and training materials that help teachers learn how to adopt citizen science projects in their classrooms. We help scientists incorporate more participatory approaches in their work, and we show students that these methods are part of the scientific data-gathering tool kit. Finally, we connect community-based groups with researchers seeking partnerships for specific projects.

The term "citizen" has become problematic in some contexts, and some are calling for a change. What do you think?

I agree that it's a problematic term. Many people feel alienated by that term, and rightfully so. Many people say when we use the term "citizen" in citizen science, it isn't about whether someone's a citizen of a country or not. It's supposed to emphasize that doing science can be part of being a "citizen of the world." A lot of people are starting to use the term "community science," which is traditionally a much more community-based version of this work. But "citizen science" is still the most widely recognized term. So I try to strike the balance and use both.

And you included both "community" and "citizen" in the center's name for that reason. What's the difference?

First, we look at what people are actually doing: who's participating, what they are getting out of it, and who's in charge. We think about citizen science projects as being led by a scientist with a research question, and people participate because they are interested and want to help. Community science, on the other hand, starts with a community or group asking research questions—often around issues in which they are very invested—and usually involves more of an environmental justice or social justice component.

When I'm talking about the larger field in general, I call it "community and citizen science." And to qualify as either of these, the data has to be used: whether it be by a scientist for basic research, a professional making a decision about natural resource management or conservation, or even a principal trying something new in her school, the data collected has to go somewhere.

Have you seen acceptance of these methods, as suitable for rigorous, peer-reviewed science, change over time?

There's an ideal vision of community and citizen science, which is that when the project is done well, the participants are learning and benefiting while conducting research with the rigor and precision needed to result in good scientific data. A win-win! But some people still debate about whether these goals can coexist. And it's true that some projects prioritize the science first at the expense of educational outcomes; the mobile app may not be user-friendly, for instance, or the results may not be returned back to participants. Others put education first, but may face more flaws in the data collected. What we do at the center is help people design projects that can do a better job for both the research and the education; when done well, each component enhances the other.

In fact, our research finds that when people know that a project is for "real research," that's when they learn the most. Participants remember that a scientist is depending on their data, so they dig in and make sure the methods are right. Community members hope to improve a local environmental policy, so they work hard to understand the research conclusions. The "realness" is what ensures the best scientific rigor and the most powerful science learning. **31**



PHOTO: Courtesy of Jessica Siegel

FOOD IS WHERE THE HEART IS

Growing up, Los Angeles native **Jessica Siegel** was such a picky eater that she refused to try even a bite of lettuce. She was a 19-year-old UC Berkeley sophomore when she finally tasted her first salad—a medley of spring greens, warm portobello mushrooms, and parmesan. "It was the whole package—the flavors, the textures, the temperatures. It was an epiphany," says Siegel, BS '98, MPH '00, RD.

Since then, food and its connection to health and wellness have become Siegel's life's work. And, she says, noting the irony, she's famous for her salads. In what she calls "a dietitian's dream job," Siegel heads nutrition for the 27-store Southern California grocer Gelson's Markets, conducting in-store consultations on everything from weight loss to disease prevention, developing recipes for the company's newsletter, and creating a line of salads that bears her name. She has even hosted a podcast, *Nutrition Bytes*, which was one of the earliest nutrition podcasts on iTunes.

The Mediterranean diet is a framework for all of this. "Thousands of studies show that populations who eat this way are healthier, live longer, have less diabetes, heart disease, cancer..." she says. And it's not all about recipes. "They also have more vitality as they age, and that has a lot to do with the social aspects of sitting down with other people to share a meal."

Siegel traces nearly all of her insight and enthusiasm back to her days as a nutrition and dietetics major and women's studies minor, a combination that helped her connect food, nutrition, health, and self-awareness. She learned to cook via technical classes on food science, a memorable internship with TV chef Martin Yan, and the Bay Area itself—the epicenter of a culinary shift to quality, seasonal ingredients like those in that

warm mushroom salad that changed everything. While earning her master's at the School of Public Health, she pursued her interest in the disease-prevention aspects of nutrition.

Knowledge about food and cooking was critical at every step. "It's such an important aspect of education, not just for nutrition majors but for everyone," she says. That's why, with her husband, Steve Tsoneff, Siegel has made a generous gift supporting the campaign to update the 1950s-era Cal Teaching Kitchen in Morgan Hall. In addition to housing the dietetics program, the facility is used by student groups and campus health services. It's also home to Personal Food Security and Wellness, a course developed for students struggling with food insecurity that focuses on how to prepare healthy meals on a tight budget. With the gift, a pledge they'll honor over the next five years, Siegel is sharing her passion for food with new generations of students and thanking UC Berkeley for a wealth of knowledge and opportunity.

More often these days, Siegel is the one getting thanked—shoppers often stop by to tell her she's made a meaningful difference in their lives. "People take me home with them," she says of her Jessica brand, delighted that her name stands for all she's learned about flavorful, healthful food. But it's the personal connections that touch her most deeply. "Customers know there is a real person putting love and care into their food. It's so gratifying."

—ANN BRODY GUY

CNR is seeking \$2.5 million in capital funds for the Cal Teaching Kitchen project. Consider pledging your own multiyear gift to show your support. Learn more about how to contribute at nst.berkeley.edu/campaign-kitchen.



Participants in a CalNat course run by the Effie Yeaw Nature Center in Sacramento upload observations to iNaturalist during an outing at Table Mountain in Oroville, California. PHOTO: Gregory Ira

Hawk Watch | Photo by Jenni Peters

This red-tailed hawk was photographed by Jenni Peters during her participation in a citizen science project led by the Golden Gate Raptor Observatory (GGRO). Peters—an elementary school science teacher who graduated from the UC California Naturalist Program (see facing page) at UC Santa Cruz last year—has volunteered with the GGRO for more than three years, helping to fit birds with metal ID bands that assist scientists conducting long-term studies of the seasonal movements of birds of prey along the Pacific Coast. “By participating in citizen science projects, I’m able to contribute to a valuable data bank and be an example for my students, showing them that anyone can be a scientist,” she says. “Through this work, I have also learned more about my local environment and made lasting friendships with people who share my interests.”



A Gateway to Citizen Science in California

The UC California Naturalist Program (CalNat) allows participants to increase their environmental literacy and stewardship through immersive courses that combine classroom and field experience in natural history, citizen science, communication training, and community service. In addition to their course hours, participants are encouraged to volunteer their time assisting with program support, restoration and conservation efforts, educational programs, and citizen science projects.

Since the program began in 2012, California Naturalists have volunteered more than **32,958 hours** working on citizen science projects.

“By contributing to research on plant phenology, monarch butterflies, and other types of ecological monitoring, these enthusiastic volunteers are acting locally to steward California’s ecosystems,” says CalNat founder **Adina Merenlender**, a Cooperative Extension specialist in the Department of Environmental Science, Policy, and Management.

GET INVOLVED!
The CalNat website offers an extensive public database of citizen science projects throughout the state. Find one that interests you at calnat.ucanr.edu/california_ppsr.

See the Bigger Picture. Make a Better World.

Support the College of Natural Resources at give.berkeley.edu. Just search for “CNR.”