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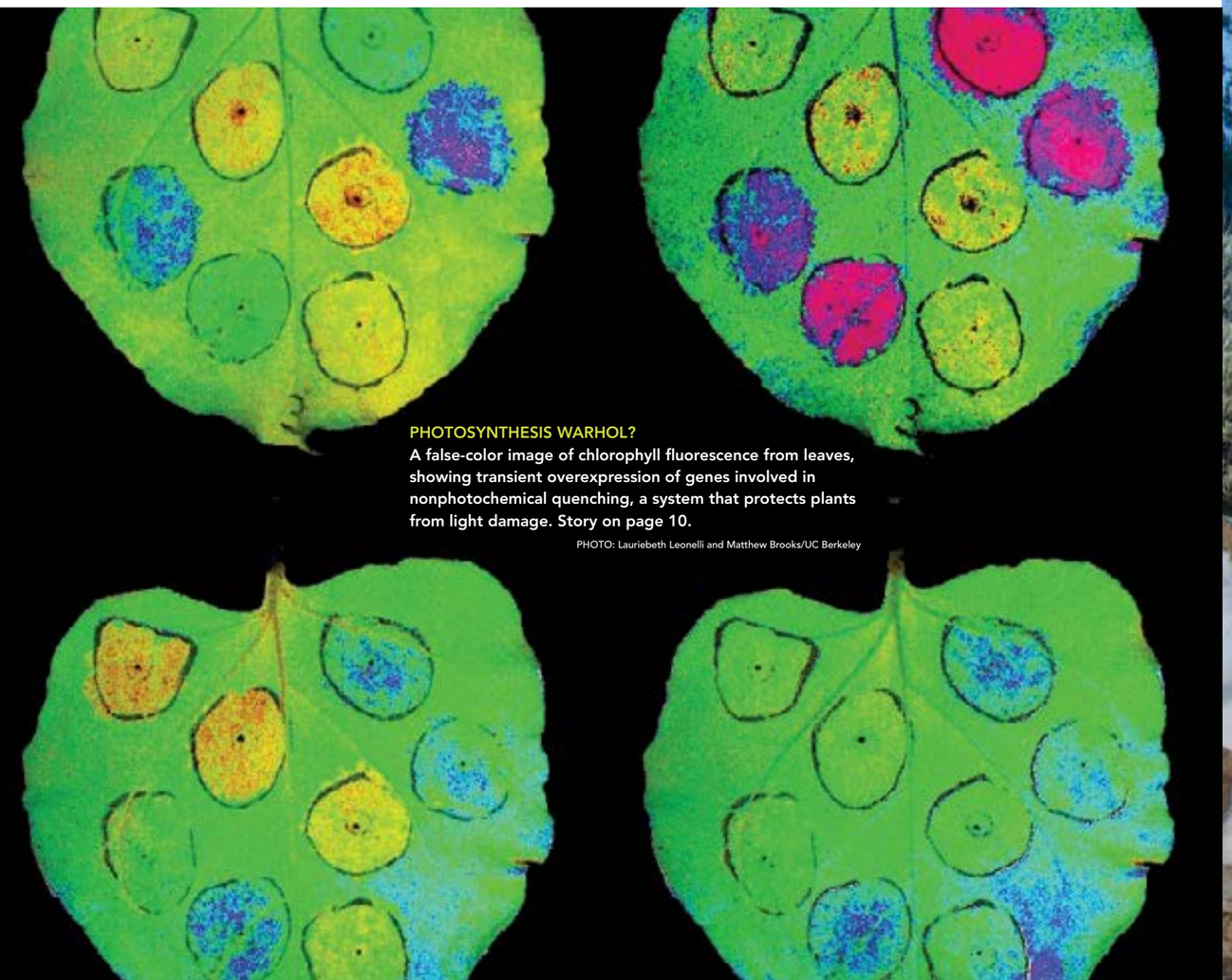

PHOTOSYNTHESIS WARHOL?
A false-color image of chlorophyll fluorescence from leaves, showing transient overexpression of genes involved in nonphotochemical quenching, a system that protects plants from light damage. Story on page 10.

PHOTO: Lauriebeth Leonelli and Matthew Brooks/UC Berkeley

BREAKTHROUGHS

UC BERKELEY COLLEGE OF NATURAL RESOURCES • SPRING 2017

Exploring the **Human-Wildlife** INTERFACE

More Efficient Photosynthesis | Fostering Diversity in STEM

LETTER FROM THE DEAN

We live in uncertain times, but there's one thing about which we can remain very certain: CNR's work is more critical than ever. We remain committed to scientific inquiry, the peer-review process, and academic excellence. We value forward-thinking research that employs new technologies and considers unexpected outcomes, and we strive to create positive, inclusive experiences for the students and researchers in our labs and classrooms.

This issue of *Breakthroughs* shows these values in action. Our feature article on increasing crop yields through more efficient photosynthesis tells the story of fundamental science that may help feed the world as we face increased drought and other effects of climate change. And our cover story follows CNR ecologists who are studying the coexistence of humans and wildlife, using both modern tools and good old-fashioned relationship-building.

Continuing on the theme of collaboration and public outreach, we highlight the Program for Graduate Students in Extension, a partnership with the UC Division of Agriculture and Natural Resources that helps students gain experience connecting science to California communities.

We also reflect on a long-running course in environmental ethics and hear from some of our premier scientists on how they foster equity and diversity in STEM fields and in their labs. And finally, we share stories of alumni and parents who are creating positive environmental impacts in the business sector, in local government, and through their generous support of CNR's efforts.

As always, I welcome your comments at gilless@berkeley.edu.

J. Keith Gilless

DEAN
J. Keith Gilless

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COVER PHOTO: Nine distinct herds of elk migrate across the state of Wyoming, traversing both private lands and public wilderness. CNR researchers are tracking their migrations to learn about the sensitive balance between wildlife and humans.

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PHOTO: Joe Riis ILLUSTRATION: Cathrine Finnema

SPRING 2017

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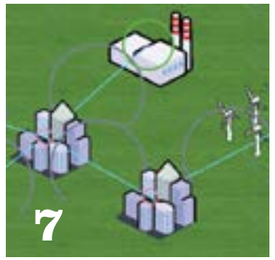
BREAKTHROUGHS



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ONLINE

VIDEO

2016–17 Albright Lectures
- Rose Marcario: "Activism in Business"
- Robert F. Kennedy Jr.: "Our Environmental Destiny"

Go to nature.berkeley.edu/albright

COVER: Photograph by Joe Riis

PHOTOS: Benjamin Kramer-Roach

POWERED-UP POO: Turning Feces into Fuel

Electricity generated from the world's collective human feces could power up to 138 million households in developing countries, according to research by the United Nations University Institute for Water, Environment, and Health. In September 2014, a Kenya-based company, Sanivation, began commercially treating human waste with the heat of the sun to create an environmentally friendly fuel source. And in August 2016, the company launched a new continuous-flow system that will enable it to take in non-sewered waste from numerous sources.

The treatment process begins with the collection of fecal waste from in-home, dry container-based toilets distributed by Sanivation and ends with a fuel briquette. A reflective parabolic disk acts like a solar concentrator with a heating fluid, continuously heating the feces within a screw conveyor.

The waste is sanitized as the heat removes harmful pathogens. Although research shows that pathogens disappear once the waste has been heated to 60 degrees Celsius (140 degrees Fahrenheit) for one hour, Sanivation errs on the side of caution and keeps it at 80 degrees Celsius for three hours. New research suggests that waste might be effectively treated in mere seconds at 80 degrees Celsius.

The company has been processing less than one metric ton of waste every month, but hopes to increase its capacity dramatically in the months ahead. "The continuous-flow system has allowed us to scale up quite a bit," said Sanivation chief technology officer **Emily Woods,** a PhD student in the Energy and Resources Group (ERG). "We'll soon be able to accept waste from other sources, not just our own distributed lavatories. We want to be an on-site waste treatment provider in areas that don't have their own treatment options."

What's more, Sanivation can now put its newer, more compact equipment in shipping containers for transport to more remote areas. For example, it recently installed a treatment system with a capacity of up to 6 metric tons of waste a month in the Kakuma refugee camp—home to refugees from South Sudan and Somalia. The team hopes to get the system processing over 10 metric tons per month by 2018. While Sanivation has focused on selling briquettes to small businesses and restaurants first, because they use larger quantities, the company plans to expand into the retail household market as well.

"Sanitation impacts every aspect of developing communities—from health to gender to livelihoods to environmental sustainability," Woods said. "Until now, less than 5 percent of human waste in Kenya has been treated properly before being dumped into the environment. I believe that by solving this problem in a cost-effective manner, we can help communities to grow in a positive way."

— KIRSTEN MICKELWAIT

Slowdown of Global Warming Is Disproved (Yet Again)

Once upon a time, mariners measured ocean temperatures by scooping up a bucket of seawater and lowering a thermometer into it. In the 1950s, ships began to measure water as it was piped through their engine rooms. Today, buoys covering much of the ocean are supplanting ship-based data collection. They report slightly cooler temperatures, because they measure water directly from the ocean rather than water that has passed through the warmth of an engine room. These modern measurements reveal that oceans have warmed more than was previously thought.

After correcting for the "cold bias," researchers with the National Oceanic and Atmospheric Administration (NOAA) concluded that the oceans have actually warmed 0.12 degrees Celsius (0.22 degrees Fahrenheit) per decade since 2000, nearly twice as fast as earlier estimates of 0.07 degrees Celsius per decade. This brought the rate of ocean temperature rise in line with estimates for the previous 30 years, between 1970 and 1999.

Published in 2015, the NOAA research was controversial, because it eliminated much of the "global warming hiatus," an apparent slowdown in rising ocean-surface temperatures between 1998 and 2012. Many scientists, including the International Panel on Climate Change, had previously acknowledged the puzzling hiatus, while those dubious about global warming pointed to it as evidence that climate change is a hoax.

Now, independent data gathered by researchers from UC Berkeley and Berkeley Earth—using satellites and robotic floats as well as buoys—confirms that the NOAA results were correct. The new study was published January 4 in the online, open-access journal *Science Advances*.

"Our results mean that essentially NOAA got it right, that they were not cooking the books," said lead author **Zeke Hausfather,** an ERG graduate student. "In the grand scheme of things, the main implication of our study is on the hiatus, which many people have focused on, claiming that global warming has slowed greatly or even stopped. Based on our analysis, a good portion of that apparent slowdown in warming was due to biases in the ship records."

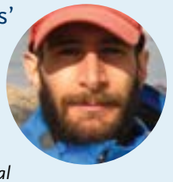
— ADAPTED FROM AN ARTICLE BY ROBERT SANDERS

Graduate Student NewsMakers

"If there's a forest, you don't want to cut it down and put a solar plant there."

Ranjit Deshmukh, *Graduate Student, ERG*
A November 2016 *Nature* news feature on renewable energy sources in Africa highlighted research co-authored by graduate students Deshmukh and Grace Wu. The researchers combined geospatial data with satellite and ground measurements to generate a comprehensive report on planning renewable energy zones in 21 African countries.

"The next time you're at a farmers' market, instead of asking your favorite vendor about their tomatoes, try asking them about their lease."



Adam Calo, *Graduate Student, Environmental Science, Policy, and Management (ESPM)*
In the October 28, 2016, *San Francisco Chronicle* op-ed "For Farmers, This Land Is Often Someone Else's," Calo discussed the challenges faced by a growing number of tenant farmers in the United States, who are often pulled between their visions and a landowner's ultimate authority. Calo called for a dialogue on equitable agriculture leases, sharing of profits resulting from capital improvements on farmland, and incentives for long-term agricultural decisions.

"The thick salt crusts kept underneath a precious record of a period when these flatlands hosted lakes and wetlands."

Marco Pfeiffer, *Graduate Student, ESPM*
A December 15, 2016, BBC news article was one of many news posts on Pfeiffer's discovery of the remnants of freshwater plants and animals buried in the arid plains of Chile's Atacama Desert. Although it is now considered the driest place on Earth, the desert may once have been more lush—even habitable—Pfeiffer's research suggests.

New CRISPR Systems Found in Tiny Microbes

UC Berkeley scientists have discovered two simple systems similar to CRISPR-Cas9—a gene-editing tool that has revolutionized biology—in previously unexplored bacteria that have eluded efforts to grow them in the laboratory.

The new CRISPR systems are highly compact, befitting their presence in some of the smallest life-forms on the planet. If these systems can be reengineered as CRISPR-Cas9 has been, their small size could make them easier to insert into cells to edit DNA, expanding the gene-editing toolbox available to researchers and physicians.

"These are particularly interesting because the key proteins in these CRISPR systems appear to have the same role as Cas9, but are distinct from it. It's part of a minimal system that has obvious potential for gene editing," said **Jill Banfield,** a professor of environmental science, policy, and management (ESPM).

Banfield and **Jennifer Doudna,** a professor of molecular and cell biology (MCB), published a report on their discovery in the journal *Nature* in December 2016.

In CRISPR-Cas gene-editing systems, the Cas protein acts as the scissors. When targeted to a specific sequence of DNA, the Cas protein binds and severs double-stranded DNA. The new discovery nearly doubles the number of simple and compact CRISPR-Cas systems potentially useful as laboratory and biomedical tools.

— ADAPTED FROM AN ARTICLE BY ROBERT SANDERS

CRISPR ON CAMPUS

The **Innovative Genomics Institute** was launched two years ago as a UC Berkeley–UCSF collaboration aimed at understanding how CRISPR-Cas9 gene editing can be used to develop new disease therapies. On January 25, the institute, which is directed by MCB professor **Jennifer Doudna,** announced a plan to invest $125 million into expanded research on the planet's major crops and poorly understood microbiomes over the next five years. ESPM professor **Jill Banfield** will lead the microbiology group, and plant and microbial biology (PMB) professor **Brian Staskawicz** will direct the agricultural arm.

Secrets of "Boy in the Bubble" Disease Are Revealed in a Single Genetic Mutation

Researchers at the College of Natural Resources were part of an interdisciplinary, international research team that identified the rare genetic mutation responsible for a unique case of "Boy in the Bubble" disease, or severe combined immunodeficiency (SCID), a deadly immune system disorder. The researchers found that the cause was a mutated version of a gene called BCL11B, which also plays an unexpected role in the normal processes of immune system development. The study was published December 1 in the *New England Journal of Medicine*.

"This is a gene that had never been associated with SCID before, which required more advanced genome analysis techniques to discover," said PMB professor **Steven Brenner,** a co-author of the study. "Moreover, unlike variants in every other known SCID gene, this mutation is dominant, which means you only need one copy of [it] to disrupt multiple aspects of development."

The work signals the beginning of a new era of genomic medicine in which technology is enabling scientists to learn a great deal about a disease—and even new facts about normal biology—from a single patient. In this case, researchers were able to unearth the potentially unique underlying genetic cause of one patient's disease and develop a deeper understanding of how the immune system develops.

— ADAPTED FROM AN ARTICLE BY BRETT ISRAEL

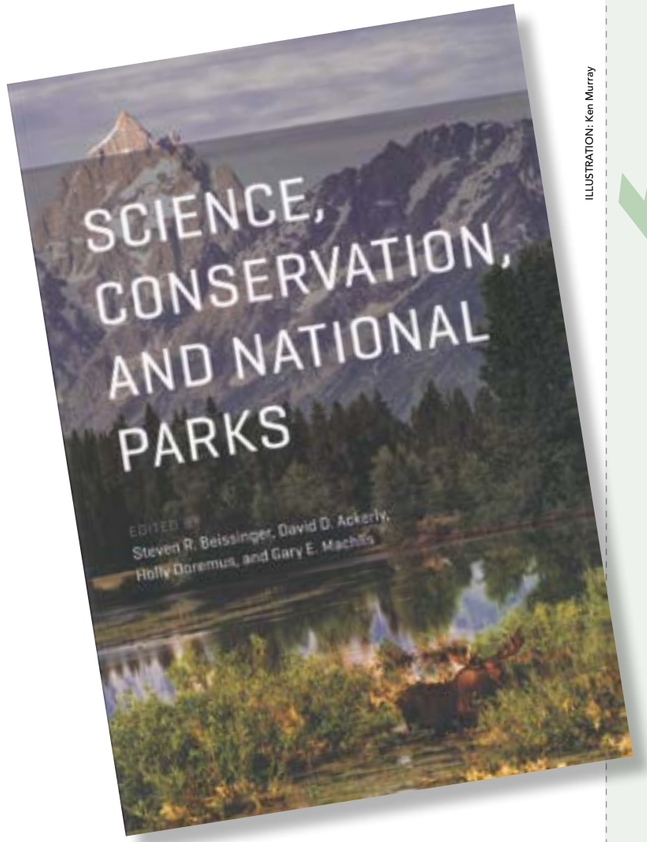


ILLUSTRATION: Ken Murray

Science on—and for—Our National Parks

In anticipation of the 2016 national parks centennial, UC Berkeley's 2015 "Science for Parks, Parks for Science" summit had two main goals: first, to commemorate the 1915 UC Berkeley conference that catalyzed the creation of the National Park Service; second, to convene thought leaders to envision strategies for a second century of science on parks and their critical relationship to people and biodiversity.

The summit's presentations are compiled in a new book, *Science, Conservation, and National Parks,* available now from the University of Chicago Press. Examining the major challenges confronting parks and protected areas throughout the world—including how to best engage people in parks—the book's contributors address key conservation and stewardship issues including climate change, pollution, invasive species, and the rapid loss of biodiversity.

ESPM professor **Steven Beissinger** co-edited the book with **David Ackerly** (integrative biology), **Holly Doremus** (law), and Gary Machlis (professor of environmental sustainability at Clemson University and science adviser to the director of the National Park Service).

— JULIE GIPPLE

Climate Change Could Kill Off Parasites, Destabilizing Ecosystems

Photogenic animals, from polar bears to people, aren't the only creatures under threat from global climate change. A new review by CNR researchers suggests that the phenomenon also threatens parasites with extinction, which could have big consequences for ecosystems.

A vast majority of the research into parasites and environmental change focuses on how hosts, particularly humans, will be harmed. But few studies have addressed how the loss of parasite biodiversity may affect ecosystem connectedness, and health and biodiversity as a whole.

Now, research co-authored by postdoctoral researcher **Carrie Cizauskas** and graduate student **Colin Carlson**—both in the lab of ESPM professor **Wayne Getz**—suggests that parasites are as prone to extinction due to climate change as any other organism. The study, which was published January 12 in the journal *Royal Society Open Science,* predicts that losing parasites could destabilize ecosystems in many ways, such as by increasing more virulent disease, altering the food web, or changing host physiology.

Previous work from these researchers has called for further research into parasite vulnerability from parasites' perspectives, rather than primarily focusing on hosts, and has also outlined ways to potentially conserve parasites. The new study outlines actionable items for researching the vulnerability of parasites. A forthcoming review from Cizauskas and Carlson attempts to quantify parasite extinction risks using existing data and modeling.

"Ultimately, our goal is for this review to act as a catalyst for further research efforts and discussions regarding the important and little-addressed topic of parasite vulnerability in the face of climate change," Cizauskas said.

— ADAPTED FROM AN ARTICLE BY BRETT ISRAEL

PHOTOS: Adam Schlender and Gregory Crutsinger/Parrot

Seeing the Forest for the Trees

Todd Dawson's field equipment always includes ropes and ascenders, which he and his team use to climb hundreds of feet into the canopies of the world's largest trees, California's redwoods. It's laborious work, but he'll soon be getting a little help. From drones.

Dawson, a professor of environmental science, policy, and management (ESPM) and of integrative biology, has teamed up with a company called Parrot to test using drone-based research tools to monitor the Sierra Nevada's giant sequoias more intensively. The new tools will help him learn how the trees utilize water and sunlight, as well as predict how they will deal with a warmer Earth and changes in water supply.

The need is urgent, Dawson said. Since 2010, more than 102 million trees, mostly pines and firs, have died in California because of drought—62 million in 2016 alone. Dawson and others wonder why the pines and firs are succumbing while thousand-year-old sequoias survive, and whether that trend will continue.

Dawson and Gregory Crutsinger, a plant ecologist and the head of scientific programs at Parrot, performed their first test on a "quadcopter" drone, which is equipped with a state-of-the-art multispectral camera that takes photos in red, green, and two infrared bands. Called the Sequoia, the camera works like more expensive satellite and airborne sensors, measuring the sunlight reflected by vegetation in order to assess physiological activity or plant health.

"Before, a team of five to seven people would climb and spend a week or more in one tree mapping it," Dawson said. "With a drone, we can do that with a two-minute flight. We can map the leaf area by circling the tree, then do some camera work inside the canopy, and we have the whole tree in a day."

After the data and photos were stitched together by a software program called Pix4D, Dawson and Crutsinger ended up with a three-dimensional representation of the foliage that Dawson's team had never seen before—information that will be used to determine how much carbon the tree takes up each day and how much water it uses. This will provide the basis for assessing what might happen with higher carbon dioxide levels in the atmosphere and less water on and in the ground.

"With repeat flights, you can watch a forest grow without ever actually measuring any trees in the forest," Dawson said. "I think drone technology holds a lot of promise to do some very innovative science over time and in three-dimensional space with a relatively cheap tool. It's really pretty amazing."

— ADAPTED FROM AN ARTICLE BY ROBERT SANDERS

TREE MORTALITY TESTIMONY

ESPM professor **Scott Stephens** spoke at the Little Hoover Commission's public hearing on California forest management in Sacramento in January. He provided background on the causes and magnitude of tree losses happening throughout the state, and he offered suggestions for both legislation and forest management techniques that could restore resilience to California's forest ecosystems.

SCREENSHOT: Courtesy of Michael Cohen

Gaming the Grid

As the clean-energy economy grows, sustainable sources of electricity are being added to power grids around the world at an increasing rate. Keeping those grids stable and affordable through "renewables integration" has become an urgent challenge. But experts are concerned that necessary grid improvements could be slowed or blocked by an inadequate power-engineering workforce or by uninformed voters or lawmakers.

While studying energy-system modeling with the Energy and Resources Group, **Michael Cohen,** PhD '16, wanted to help inform the public about what it means to add clean energy to our power grids. Taking inspiration from "edutainment" simulation video games like the SimCity series, he created Griddle, a PC game that enables players to design, operate, and grow their own power grids. Players tackle real-world challenges like meeting California's renewable energy regulations while controlling costs or stabilizing Japan's power system in the aftermath of the 2011 earthquake and tsunami. In the process, they learn about the historical operation of traditional power systems, as well as changes triggered by new technology and environmental awareness.

Cohen also developed a high school curriculum to accompany the game prototype and tested both at local schools. He noticed that students wanted to dive into the game quickly, jumping ahead of his planned levels to add wind and solar energy sources early on. "From a values perspective, that was very exciting!" he said. But students had difficulty managing blackouts and controlling costs, Cohen added.

"They learned about the complex realities of adding renewables, from the intermittency of wind and solar power to the cost of implementation." And he hopes that intrigued them. "I want more people to see that the migration to more sustainable energy sources is a challenge, yes, but an interesting and exciting one."

Cohen is now working as a power-systems engineer for the Union of Concerned Scientists. He hopes to find more funding to further develop Griddle and eventually make it more widely available.

— JULIE GIPPLE

Five Key Lessons

ESPM 161

Environmental Philosophy and Ethics

Taught at the College of Natural Resources by Professor **Carolyn Merchant** since 1979, Environmental Philosophy and Ethics begins with a background on the history of philosophy. The course then investigates our current global ecological crisis, dips back into ethical systems of the past, and applies new ethical and philosophical approaches to today's problems. In addition to common environmental themes like population and sustainable development, students discuss such topics as genetic engineering, ecofeminism, deep ecology, and Eastern philosophy—all with an awareness of how race, class, and gender play a part. These five key lessons guide students as they each form a personal environmental ethic.

1 **Explore your ethics.** Informing every decision, every negotiation, and every approach to a major environmental issue is an ethical stance: What is good? What is right? How ought we to act? In turn, all ethics have philosophical principles, histories, and assumptions at play. Learn to identify the underlying ethics of your colleagues and fellow negotiators, as well as how to apply your own.

2 **Choose to care.** Whatever your occupation, choose an environmental issue you care deeply about and devote time and energy to solving it.

3 **Creativity is critical.** Think about new approaches and new angles on resolving environmental problems.

4 **We are all one earth.** We share this planet with all living and nonliving beings. Considering the interactions among all of them is crucial to how we move forward.

5 **Race, gender, and class matter.** Consider these factors when examining any environmental issue. Propose gender-based, socially sensitive solutions to environmental problems.

ON THE GROUND

Graduate Students in Extension

The Cooperative Extension advisors and specialists of UC's Division of Agriculture and Natural Resources (ANR) truly spend their careers "on the ground." They use their scientific expertise and communication skills to provide practical, research-based advice to Californians with the goal of promoting healthy people, healthy food systems, and a healthy environment across the state.

In 2013, a group of graduate students in the Department of Environmental Science, Policy, and Management (ESPM), seeking out faculty support, successfully collaborated with ANR to launch the Program for Graduate Students in Extension (GSE). Participants receive up to a year of funding to conduct applied research and outreach to California communities, coordinate workshops and training events, and co-author materials with ANR academics. Over the course of the three-year pilot program, 14 students from across the College of Natural Resources have participated.

"There's really no program quite like this, where students can gain hands-on, graduate-level training in extension and outreach," says ESPM professor **John Battles,** who chaired the program's steering committee. He adds, "We're grateful to all the ANR advisors and specialists who have offered invaluable mentorship to student fellows."

SUSTAINABLE FOOD SYSTEMS AND CLIMATE EDUCATION

Alana Siegner (Energy and Resources Group, 2016–17 fellow) believes that to ensure the environmental sustainability of agricultural landscapes and to improve health outcomes for young people, it's important that students understand the scientific and social causes and consequences of climate change as it plays out in the U.S. food system. During her fellowship, she adapted existing climate change curricula to fit within farm-to-school programs, integrating food- and farming-specific examples into general lessons on climate adaptation and mitigation. The lessons, designed for students in grades 8 through 10, are hands-on, interdisciplinary, and solutions oriented, unfolding in both the classroom and the school-garden environments. Siegner piloted the curricula and other professional development resources with teachers at schools in Oakland and in Washington State's San Juan Islands.

To learn more about the GSE program, visit ucanr.edu/sites/ggce.

FORESTRY AND ECOSYSTEM EDUCATION

Stella Cousins (ESPM, 2014–15 fellow) collaborated with the Forestry Institute for Teachers, a free program that provides K–12 teachers in California with knowledge and tools for teaching their students about ecosystem science and forest resource management. In addition to presenting current research to participating educators, she shared do-it-yourself miniature microscopes that can help learners of all ages explore seeds, cells, fur, and other tiny wonders. Magnifying tree-core samples from the Sierra Nevada as an example, she demonstrated how a lesson in dendrochronology can facilitate classroom learning on the ways forests grow and are shaped by climate. Cousins says, "I hope that this project will support existing efforts to make sound and sustainable ecosystem-management choices, and also help foster lifelong curiosity in California's youth about the natural world."

CONSERVATION AND LAND EASEMENTS

Conservation easements are currently one of the primary channels for protecting private land. Since easements restrict development for both current and future owners, resale value is presumably diminished, and landowners are typically compensated with a one-time payment from a conservation group. **Reid Johnsen** (Agricultural and Resource Economics, 2016–17 fellow) wanted to explore the relationship between rancher identity, community, and potential preferences for alternative payment structures. He surveyed landowners in Marin and Sonoma Counties to gauge their support for different options, including leases and annual payments for ecosystem services. He also constructed an economic model of stakeholder behavior to help assess which payment structure delivers the greatest combined welfare to landowners, conservation groups, and the public.

CLIMATE-RESILIENT AGRICULTURE

Despite several advances in modeling techniques, climate projections are not widely used in agricultural decision-making. **Kripa Akila Jagannathan** (ERG, 2015–16 fellow) wanted to bridge this gap between climate science and decision-making needs by improving the understanding of what farmers consider relevant climate information. She interviewed almond growers in California about how they'd previously used climate information, what climatic variables were most relevant to them, and the content and communication methods that could make information on future climate more usable. Jagannathan's interviews showed that almond growers have experienced changes in climate over the past few decades that have affected plant growth. She hopes that providing growers with appropriate information on past trends and future projections can help them to make decisions that are better adapted to future climate.

HUNTING AND CONSERVATION

Luke Macaulay (ESPM, 2014–15 fellow) surveyed private landowners and land managers in California to determine how recreational hunting may influence decisions regarding land-use and conservation practices. He regularly spoke on his survey findings and ran a workshop in Montana to encourage cooperative conservation efforts between hunters and environmentalists. "The feedback from the advisors on my mentorship team was invaluable in improving the quality of my research," he reflects. The experience also had an impact on his career: In 2016, Macaulay was hired by CNR as a Cooperative Extension specialist in rangeland planning and policy.

PHOTOS: Courtesy of Alana Siegner, Stella Cousins, Kripa Akila Jagannathan, and Luke Macaulay.

Seeing the LIGHT

A Berkeley-Illinois collaboration experiments with photosynthesis to increase crop yield

By Zac Unger, MS '00 Environmental Science, Policy, and Management

Illustration by Cathrine Finnema

Photosynthesis. It's one of the first lessons taught in any high school biology class, and yet we take this almost alchemical process for granted. The sun shines, oxygen and carbohydrates are produced, life on Earth is sustained. We're surrounded by the evidence of photosynthesis' success, from mighty redwood forests to the air we breathe or even the humble leaf of iceberg lettuce that adorns our sandwich.

It's a surprise, then, to learn that photosynthesis isn't really very efficient, often utilizing only 1 percent of available sunlight. Part of the reason is that plants live in the real world, not in the tidy equations of long-forgotten Bio 101 textbooks. Clouds pass overhead, wind blows branches in and out of sunlight, and many leaves are literally overshadowed by higher-tier foliage. Moreover, leaves are surprisingly vulnerable to damage from bright light, and plants have evolved a photoprotective mechanism, called nonphotochemical quenching (NPQ), that allows them to blow off energy from excess light in the form of heat.

"The problem," says Professor **Krishna Niyogi,** chair of the Department of Plant and Microbial Biology, "is that plants are really good at turning on this photoprotection in bright-light conditions, but they turn it off much more slowly when they're back in the shade." As a result of this lag time, leaves don't perform photosynthesis as effectively as they could; they dump valuable solar energy while constantly shifting between sun and shade throughout the day.

But what if there were a way to encourage plants to turn down the dimmer setting more quickly? Imagine the cumulative effect on an entire field of crop plants if you could coax just a little more production out of each individual leaf. Working with a far-flung team of co-researchers, Niyogi theorized that a fairly small genetic modification might increase the "relaxation rate" of NPQ in plants, allowing them to get back to photosynthesis more quickly. Theoretical modeling done by other labs suggested that this could increase crop yields in the neighborhood of 10 to 30 percent—some absolutely staggering numbers.

The lightbulb moment

In 2007, Niyogi happened to run into fellow biologist Dr. Stephen Long of the University of Illinois at a conference, and they batted around ideas that eventually led to Niyogi's applying for a National Science Foundation (NSF) grant. "They said it would never work," Niyogi recalls, without any apparent hard feelings. "And we didn't get funded." To be fair, the idea of a 20 percent increase in productivity must have sounded a little far-fetched, given that increases in crop yield per acre by all other methods combined have plateaued at about 1 percent per year.

Fortunately for Niyogi and his team, the NSF wasn't the only game in town. "We're always looking for breakthrough discoveries," says Katherine Kahn, senior program officer at the Bill and Melinda Gates

"I should have had more faith in our modeling. I've had a few lucky breaks in my career, but this is the biggest."

— Stephen Long

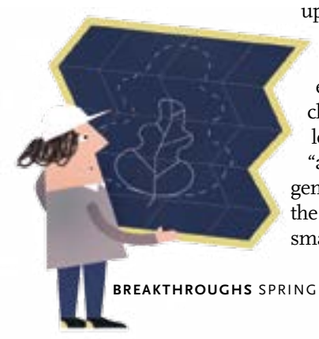
Foundation (and an accomplished plant biologist herself). "We'd talked to scientists in the field and looked at the literature, and we were specifically interested in increasing photosynthetic efficiency."

But at that point it wasn't clear if the idea truly had real-world promise. Then Niyogi and Long suggested their approach, and, according to Kahn, "it was just an 'aha' moment for me and my boss. Their thinking was very clear about how to improve crops; they had a lot of modeling, some initial data, and a testable hypothesis." The foundation made a five-year, $25 million investment, funding Niyogi and Long's project—and a half dozen others—under the umbrella of its Realizing Increased Photosynthetic Efficiency (RIPE) project.

A potential game changer in the developing world

Moving from a promising model to large-scale success is complicated, but when the Gates Foundation gets involved, you can be sure that it won't be satisfied with exciting theoretical musings. "We invest in projects that will result in agricultural transformation for smallholder farmers who need to get their families out of poverty," says Kahn. For rural communities eking out a living in the developing world, increasing yields without increasing acreage could be a game changer.

Niyogi and his postdocs, **Lauriebeth Leonelli** and **Stéphane Gabilly,** began attempting to prove their concept with tobacco plants, not because they valued that crop, but because it is well studied and easily manipulated: the white mouse of botany. In the lab, they altered three genes that they hoped would speed up the time it took plants to recover from photoprotection. Using a technique called transient expression, the researchers changed discrete spots on individual leaves, which Niyogi described as "a high-throughput way of testing genes in combination so we can see the resulting phenotype on even just a small section of a leaf."



For help with the fundamental science of how NPQ works, Niyogi collaborated with Berkeley's **Graham Fleming,** a chemistry professor who specializes in ultrafast spectroscopic techniques of working with light on a nanoscale. "This is all so very complicated to study, because if you start pulling pieces out, nothing happens," says Fleming. "It's a whole system, and so doing these simplifying experiments is crucial." Eventually the team developed stable plants that could pass the desired characteristics on to subsequent generations.

For the critical next stage of greenhouse and field work, the project shifted to the University of Illinois and Long's lab. "The modeling predicted that we could get a 20 percent increase in yield," says Long. "I'm not sure I was convinced that it would actually happen, though. Many considered that if there were a free lunch out there, evolution would have found it. Others had tried this with single genes or mutants, but ours was the first study to try this three-gene combination and take it from in silico prediction all the way through to testing with replicated field-plot trials."

"This study is so remarkable," says Niyogi. "The idea for speeding up the relaxation rate of NPQ came from a theoretical paper from 12 years ago out of Dr. Long's lab. We came up with a way to accomplish this and did the proof-of-concept lab work at Berkeley, but we don't have the growth facilities and fields that Illinois does. Neither of our labs could have done this on our own."

Once the modified tobacco plants were allowed to grow in the field, the results were every bit as stunning as the modeling had predicted: a 14 to 20 percent increase in total dry weight per plant. "I should have had more faith in our modeling," says Long. "But when we saw success in the greenhouse and then were able to replicate it in field trials, well…I've had a few lucky breaks in my career, but this is the biggest."

The challenge of scaling up

The leap from a Berkeley laboratory to an Illinois test plot will be dwarfed by the next step: helping this technology to enter the agricultural mainstream. Luckily, that sort of scaling is exactly what the Gates Foundation does best. It requires that the projects it funds develop a global-access strategy that details exactly how the technology will be made available to those most in need in the developing world. "Sometimes that means partnering with the private sector," says Kahn, in order to access the mass production and distribution channels enjoyed by for-profit companies.

First, of course, the project will have to expand beyond tobacco. "We should have an idea of how this works in rice within a year or so," says Niyogi. And

PHOTO: Jim Block

under the umbrella of the RIPE project, the Gates Foundation has been connecting American scientists with counterparts in Nigeria and Ghana in hopes of expanding the technology to cowpea, a highly nutritious legume common in West Africa.

The idea is not without its detractors, however. Plants altered in this way fit the definition of genetically modified organisms, which have become a hotly debated flash point. Niyogi and the others are sensitive to this concern, but remain confident that the process is safe. "We put in extra copies of a gene that is already present in the plant," says Long, "so, while it is genetic engineering, we don't have to introduce foreign material." In the future, it may even be possible to get the same effect by editing promoter or repressor elements—basically, getting a plant to express more of a gene that it already possesses.

The Gates Foundation takes the 30,000-foot view, says Kahn. "Things look different in rural Tanzania versus Berkeley, where issues of economic survival are less prominent. We want to do whatever we can to help small farmers get what they need in a way that's safe and that respects their choices."

"What every scientist hopes for"

Beyond crop yield, the promise of the research extends to sustainability and food security. Climate change is already altering everything from cloud patterns to pest infestations; increasing yield per plant is an excellent way to stabilize overall production without putting more acres into cultivation. Even better, this increased caloric production doesn't require more water—a huge benefit when dealing with drought and newly unstable atmospheric conditions. If these techniques prove effective for growing biofuels, the process might even reduce reliance on coal and oil.

"This study is so remarkable, because neither of our labs could have done this on our own."

— Krishna Niyogi

The UN's Food and Agriculture Organization has issued a warning that global food production needs to increase by 70 percent by 2050 to keep pace with the expanding population. Current technologies simply aren't prolific enough to meet that large a goal in so short a time. And while increasing photosynthetic efficiency alone can't solve all the world's food problems, it's clearly one of the most promising technologies on the horizon.

Such potential impact is a dream come true for many basic scientists, who rarely see the real-world application of their research. Fleming remembers some words of wisdom from his thesis adviser, who told him that "there's no such thing as useless science—you just don't know when it's going to be applied."

Niyogi agrees. "At the beginning of grant proposals, everyone always says, 'If this all works, it will have massive applications,'" he says. "But I honestly never thought I'd see something this big come out of basic research. It's what every scientist hopes for. It feels awesome."

Professor Arthur Middleton (pictured) and wildlife photojournalist Joe Riis spent two summers tracking elk migrations in the Greater Yellowstone Ecosystem, covering more than 1,500 miles on horseback and spending weeks at a time in remote locations.

Conflict and COEXISTENCE

CNR ecologists explore the frontier of the human-wildlife interface

By Nate Seltenrich | Photography by Joe Riis

The film *Elk River* opens with a shot of two female elk trudging up a steep, snow-dusted slope in the remote Absaroka Range, east of Yellowstone National Park. Captured by a camera trap in just the right spot, the image offers a rare and fleeting glimpse into an arduous journey made twice each year by migratory elk into and out of the park.

In the next scene, a net fired from a low-flying helicopter ensnares another elk racing across a frozen landscape. Soon she will be ready to begin her spring migration from this low-lying valley outside Yellowstone where she's wintering, over the Absarokas' jagged peaks, and into the high country—and relative safety—of the southeastern corner of the world's oldest national park.

But ecologist **Arthur Middleton** doesn't know all this yet. Crouched in freshly fallen snow as he watches the helicopter follow and then overtake the elk, he awaits his chance to find out. With the elk momentarily disabled, Middleton springs into action. He and a colleague blindfold the animal and strap her legs together to immobilize her while they work. Middleton slips a black GPS collar, a bit wider than a man's belt, over the elk's head. He tightens and secures it, then removes the restraints and in one fluid motion steps back, pushes the animal forward, and releases his hold. The elk rises to her feet and dashes out of frame. "There she goes," he says as he watches her flee. "We'll start getting locations and then find out where she migrates."

A HARSH MIGRATION

What Middleton has learned by tracking the movements of this elk and dozens more members of the Cody Herd since 2014 is nothing short of incredible. Twice each year, these elk scale a series of 11,000-foot passes in the Absaroka Range. They drop and then climb 5,000 feet from peak to valley to peak, crossing swollen rivers—pregnant cows and nursing calves included—before reaching their destination on one side or the other.

Even more incredible is that the physical demands of this 60-mile traverse are not, in a sense, the elks' greatest concern. Instead, it's the invisible and seemingly arbitrary borders they must cross along the way: fences, roads, cattle pastures, and even subdivisions. On the patchwork of public lands and private ranches in Wyoming, Idaho, and Montana where many of Yellowstone's elk—not just the Cody Herd—spend nearly half of each year, food is sparse and danger is everywhere.

In the fall, from the moment they first leave the park, the animals are hunted by humans, in addition to the usual wolves and grizzlies. When they arrive on the open prairie of the low country a couple of days or weeks later, the hunting pressure only intensifies. The elk band together in large groups in a bid to survive what Middleton describes as a "long, quiet, white, cold winter where they're just trying to hang on." The animals may also be harassed and hazed on their winter range by ranchers looking to avoid competition for their cattle and maximize the success of their ranch, he says.

A MUTUAL RELIANCE

The threats do go both ways. Elk carry a disease, brucellosis, that can be harmful to cattle and incredibly costly to ranchers. They knock down fences and eat grasses that can be valuable to hungry cattle in drought years. They attract not only wolves and bears but also trespassing hunters who can open gates and knock down fences just as easily as the elk.

Using existing GPS-collar data shared by many agencies and universities—and filling gaps by gathering new migration data over the course of two years—Middleton and colleagues created this map depicting the extensive movement of more than 20,000 elk in nine major herds across both public and private lands in Wyoming, Montana, and Idaho.

Source: Atlas of Wildlife Migration: Wyoming's Ungulates
Cartography: Jim Meacham and Alethea Steingisser, University of Oregon InfoGraphics Lab
Elk data contributed by: Wyoming Game and Fish Department; Montana Fish, Wildlife, and Parks; Idaho Fish and Game; National Park Service, US Fish and Wildlife Service; Wildlife Conservation Society; Wyoming Cooperative Fish and Wildlife Research Unit; Iowa State University; and Yale School of Forestry and Environmental Studies.

Even to ranchers who may otherwise cherish elk, these are serious concerns.

And yet the elk require ranchlands to survive. "These migrations wouldn't persist today if not for some of these big cattle ranches that have been kept intact," says Middleton, who joined the Department of Environmental Science, Policy, and Management (ESPM) last summer after finishing postdoctoral work at Yale. "Fundamentally, the space has stayed open in a lot of places, and that's the most important thing."

It's just one example of how the relationship between wildlife conservation and human activity is far more nuanced than it may appear, he says. Through his research and outreach, Middleton has discovered a mutual reliance between animal and human: The elk need ranchers for winter forage, for example, while hunting guides and outfitters owe elk their livelihoods.

These relationships have long been framed in terms of opposition and conflict. But Middleton, informed by what he knows about the migrations of Yellowstone's elk, seeks a higher road. He hopes to shift the tone of the conversation toward one of cooperation and common ground—not merely for the benefit of the elk, but also for the health of what is known as the Greater Yellowstone Ecosystem and for the good of anyone who works, lives, or travels in this mostly wild part of our country.

"There are things that you can learn from people around a fire in the backcountry that you're simply not going to learn in the way that we communicate in the world today."

— Arthur Middleton

"A QUIET CARNIVORE RECOVERY"

California is also poised to see growing numbers of similarly complex human-wildlife interactions, says fellow ESPM ecologist and professor **Justin Brashares.** The big difference is that instead of sustaining existing populations, the state's land managers and wildlife experts are increasingly tasked with managing the return of long-suppressed predators to the landscape, including wolves, mountain lions, badgers, foxes, coyotes, bobcats, and bears.

State and federal policies once incentivized the removal of these carnivores, even offering bounty payments, Brashares says. The last California grizzly, or golden bear—state animal and mascot of UC Berkeley—became a victim of such practices in 1922. The gray wolf was exterminated shortly thereafter, only to make a historic return 90 years later in the form of a single young male called OR-7, who has been followed into California by several other wolves.

Beginning in the 1970s with the federal Endangered Species Act and the banning of bounties, things began to change. Poisons and leghold traps were prohibited in 1998. Next came an end to the sport hunting of mountain lions in 1990, bear hunting with dogs in 2012, and bobcat trapping in 2015. The cumulative result of these actions, which eased centuries of pressure on wild animals treated as pests, has been a "quiet carnivore recovery" happening across our state, Brashares says. And depending on whom you ask, that may be a great thing or a terrible thing.

An ecologist or environmentalist might emphasize the role of carnivores in maintaining healthy ecosystems. "What we're seeing across the state, particularly over the last 10 years, is arguably an unprecedented recovery of our wildlife communities," Brashares notes. A livestock rancher, meanwhile, might view the development with dread. "They're the ones most likely to be negatively impacted by the return of these animals." A similar divide, he notes, exists between urban and rural dwellers. "Those who face the challenges of coexistence with carnivores on a day-to-day basis tend to be more negative about their return," he says.

The rest of us tend to view the return of carnivores—particularly large, charismatic ones—much more favorably. "In more-urban communities, we often have the luxury of interacting with carnivores on our own terms, by going out and seeking them in wild settings, away from our safe living and work environments, in places like Yosemite National Park," says Brashares. His point is well taken by anyone who has lost a dog or cat to a mountain lion, let alone by commercial ranchers trying to protect their livelihood from hungry coyotes and wolves. But even so, he says, reliance on lethal control as the primary strategy for managing predators in the state is due to become a thing of the past.

NEW INSIGHTS INTO COEXISTENCE

How to behave instead is, in part, a question for science—and one that Brashares is working to answer through ongoing research at the University of California's Hopland Research and Extension Center (HREC), in southern Mendocino County, about two hours north of Berkeley. There the university owns a 5,300-acre parcel with oak woodland, grassland, chaparral, and riparian environments—and, according to recent surveys, wildlife densities on par with those in Yellowstone and Yosemite. Linked to the massive Mendocino and Shasta-Trinity National Forests, it's part of a corridor of undeveloped and protected land extending all the way to the Canadian border. As such, it commonly hosts coyotes, bobcats, mountain lions, and black bears.

The plot is also home to more than 500 sheep, on-site since the 1950s for the study of sustainable agricultural practices. But sheep, open space, and carnivores spell conflict, and the flock has regularly

Professor Justin Brashares (center) and members of his lab utilize tagging, drones, and GPS technologies to track the movement of carnivores and their prey.

PHOTO: Jim Block

"What we're seeing across the state, particularly over the last 10 years, is arguably an unprecedented recovery of our wildlife communities."

— Justin Brashares

suffered significant losses to coyote predation. The coyotes, in turn, have traditionally been shot on sight, in line with established wildlife management practices in agricultural settings.

In 2014 alone, nearly 50 lambs were killed by coyotes at HREC, and another 178 went unaccounted for. Meanwhile, 26 coyotes were killed to prevent further losses to the flock. Toward the end of the year, when **Kim Rodrigues**, BS '81 Forestry; PhD '08 ESPM, became director of HREC, she realized the current system wasn't working and set about to fix it.

Rodrigues brought on more guard dogs and a new shepherd, improved fencing, and changed the rules about shooting coyotes and other predators. She also initiated a number of research efforts, in which Brashares now plays a lead role, to critically evaluate the effectiveness of tools like dogs, fences, and "fox lights," which are randomly lit on the fields to scare off predators. And Brashares and Rodrigues are studying how to better use technology like GPS, drones, and tagging to understand the often-mysterious behavior and movement of carnivores and their prey, in hopes of gaining new insights for human-wildlife coexistence.

After Rodrigues instituted some of these changes, the numbers of lamb and coyote deaths at HREC began to decrease dramatically. In 2016, fewer than five lambs were believed to have been killed by coyotes, with another eight unaccounted for, and just seven coyotes were shot.

In a bid to make HREC a statewide hub for cutting-edge research and discussion around human-wildlife interactions, Rodrigues enlisted Brashares's help in December 2015 in hosting a community conversation with stakeholders about the management of wildlife and livestock using nonlethal methods. A second discussion is planned for this June.

"My research and extension focus is now on how we can start to explore standard operating procedures that actually have a stated goal to protect both the livestock and the wildlife, and not one or the other," Rodrigues says. "It's changing the either/or conundrum to thinking about how we really value both on the landscapes that we're managing."

THE IMPORTANCE OF INFORMAL SOCIAL CONNECTIONS

Elk River, a 30-minute film that premiered last year, is currently on the festival circuit and has just been released by *National Geographic* through its online Short Film Showcase. The documentary is replete with vivid shots of migrating elk amid Yellowstone's breathtaking scenery. But to those familiar with the workings of this landscape, it's the scenes in which Middleton chats with local ranchers and guides that resonate most.

In one such scene, he and the film crew—including collaborator and photographer Joe Riis, responsible for setting and retrieving the remote camera traps that capture, for the first time, high-quality video of elk migrating over the Absarokas—set up camp in the mountains outside the park with local guides (and brothers) Lee and Wes Livingston: tall, slender, rugged Wyoming cowboys sporting identical Stetson hats and thick brown mustaches.

Interacting with the elk is a year-round activity, explains Wes. "I love to go see the elk in the spring,

After a long day on the mountain, Middleton (left) confers with local guides (and brothers) Wes and Lee Livingston.

and then we follow them through the summer. When we take our pack trips, we show people these beautiful herds of elk up on the high-alpine meadows, grazing. In the fall, we rely on the elk for the hunting season. In the wintertime, I capture elk using a net gun from a helicopter and put collars on them for this research project here."

Reflecting on Livingston's comments now, Middleton stresses the value that informal social connections have for his research. "One of the more important aspects of my work is understanding not just the ecological system but also the human landscape in which it's now embedded," he says. "There are things that you can learn from people around a fire in the backcountry that you're simply not going to learn in the way that we communicate in the world today."

Not that he eschews modern-day methods of communication. In fact, the film itself is more than just a record of his work; it's a critical component of Middleton's mission to raise public awareness. With Riis, he conceived the idea, raised the funds, and produced the film, hiring director Jenny Nichols. The project grew out of a competitive $100,000 prize awarded to him and Riis in 2013.

The pair also created a traveling museum exhibit on the elk-migration phenomenon called *Invisible Boundaries*—it ran last year at the Buffalo Bill Center of the West in Cody, Wyoming, and the National Geographic Museum in Washington, DC, and is headed to the Peabody Museum of Natural History at Yale University next—and engaged artist James Prosek, whose paintings of Yellowstone wildlife appear in both projects.

In addition, Middleton partnered with *National Geographic* on a special issue dedicated to Yellowstone. He has even penned op-eds for the *New York Times* and the *Wall Street Journal* on other aspects of human-wildlife conflict.

But when it comes to public outreach, perhaps Middleton's greatest challenge awaits back in Wyoming, where last August he worked with the Western Landowners Alliance to cohost a three-day symposium on human-wildlife conflicts—primarily between ranchers and elk—within the Greater Yellowstone Ecosystem. Its title, "Ranchers and Scientists Exploring Solutions for the Future," was a nod to Middleton's intent to move beyond the same old discourse. "It's so easy for this to all get sucked down into 100 debates about different aspects of the problem," he says. "A big motivation for me has been to bring the wonder back into this conversation, so that we can build an identity around important ecological and cultural values in the ecosystem. People want to solve these problems, and I want to help."

Their conversation is ongoing—a workshop on invasive plants was held in March—and could continue for years or even decades. Middleton is willing to stay the course: "Personally I've started to believe that these elk migrations are the heartbeat, the pulse of the Greater Yellowstone Ecosystem," he says, "and I want to spend the rest of my life being a part of it."

WATCH *ELK RIVER*

National Geographic is featuring the documentary *Elk River* in its Short Film Showcase. Watch at **nature.berkeley.edu/breakthroughs/elk-river**

GLOBAL ISSUES, LOCAL IMPACT

BS 1982 CONSERVATION OF NATURAL RESOURCES

DAN KALB

Dan Kalb has spent his career fighting for big issues—environmental justice, clean energy, stewardship of our natural resources—both on the public-interest-advocacy side of the equation and, more recently, as city council member for Oakland's District One. Last November, he was re-elected to a second term with an overwhelming 80 percent of the vote.

By Anne Canright | Photo by Julie Gipple

Growing up in Los Angeles, he remembers, his lungs would actually hurt from the air pollution. He also recalls the first Earth Day, in 1970, which made him aware of broader environmental issues. By high school, he'd shed his childhood ambitions of becoming an astronaut or a TV director and set his sights on environmental science.

Kalb found the College of Natural Resources after two years at UC Santa Barbara. "I wanted to look at things with a more global perspective," he explains. The conservation of natural resources major—now known as conservation and resource studies—was exactly what he was looking for: "a balance between academic learning and real-world experience." As a student, he interned at the Bay Area's Metropolitan Transportation Commission, working on environmental and transportation policy. He also volunteered with the public watchdog group CalPIRG, contributing to state efforts to protect water resources.

Since then, Kalb has spent most of his professional life working for nonprofit advocacy organizations. "Some of these groups have carried over into other public interest causes," he says. "But my first passion has always been environmental protection for ourselves and future generations." His résumé includes such organizations as the Sierra Club and California Common Cause.

Implementation is critical

From 2003 to 2012, Kalb served as California policy director for the Union of Concerned Scientists (UCS). "I worked on a range of issues that dealt with climate change, air pollution, renewable energy, and clean transportation," he says. "I would draft legislation and work with state legislators, regulatory agencies, and the governor's office to enact and implement important policies that reduce California's contribution to climate change and promote the use of clean sources of fuels. Implementation is critical: Just passing a law isn't enough."

While at UCS, Kalb played a leadership role in the passage of the 2011 law mandating that one-third of the state's electricity come from clean, renewable sources by 2020. (Last year, that proportion was increased to one-half, and the deadline extended to 2030.) He also worked to reduce the number of polluting diesel vehicles on the road and to require labels on new cars for sale indicating their smog and greenhouse gas pollution rankings.

While working in public interest advocacy, Kalb interacted with hundreds of state and local elected officials. They're the ones with the true authority, he observes, "if they choose to use it, to have a real impact and enact useful policy" on a broad scope of issues. So when a seat in his local council district opened up in 2012, he threw his hat in the ring. With endorsements from the Sierra Club and the Alameda County Labor Council, and lots of miles spent walking precincts, Kalb won, and he's been working tirelessly ever since. "Just ask my wife," he jokes.

A commitment to community

Kalb's focus is still firmly on natural resources and the environment. One piece of legislation of which he's especially proud prohibits the handling and storage of coal in Oakland. "That has a benefit locally, in terms of public health, and globally, in terms of climate change," he says. On a similar note, he authored a resolution requiring the city to divest from all holdings in fossil fuel. He serves as president of the county-wide program Stop Waste, which recently widened a plastic bag ban, and he successfully pushed for an expansion of composting. He has also worked to add more bike lanes in Oakland and is currently engaged in creating a community-choice energy authority for Alameda County.

"You need to have your ducks in a row and provide the scientific backing to support what you want."

Environmental protection may be where his passions lie, but as a council member Kalb deals with a host of other wide-ranging issues. He ticks off a few: crime reduction and ex-offender rehabilitation; police accountability and governmental ethics; affordable housing and funding for public libraries. In recognition of his work on the latter issue, he was named California Public Library Advocates' legislator of the year in 2015. "Oakland is a wonderful city with a rich diversity," he says. "I love working on the challenges we face—both locally and beyond."

Throughout his career—whether engaged in big-issue activism or talking with constituents about their real-world needs—Kalb has remembered that at the heart of all the hard work is community. And community is something he continues to appreciate about CNR and the conservation and resource studies major. "The people who have been in the program over the years and decades feel a real kinship to one another and a sense of pride because of the commitment to both academic excellence and real-world impact." That commitment continues to fuel Kalb as he tries to help make a better region and a better world. "And with the new administration in DC," he adds, "we must work even harder to protect our sisters and brothers and our planet."

Oakland city council member Dan Kalb and local residents prepare for a city cleanup day.

PHOTO: Courtesy of Dan Kalb

Q&A

Female Bench Scientists Talk Diversity

Four CNR faculty on creating inclusive environments in science.

By Kirsten Mickelwait | Photography by Jim Block

Michi Taga

Microbiologist
Associate Professor, Plant and Microbial Biology (PMB)

Michi Taga is researching how microbes interact to form complex communities.

What is your area of research, and what is its potential impact? My research focuses on understanding how microbes interact with each other to form complex communities. Bacteria and other microbes inhabit every corner of the planet, and they do incredible things like recycling organic matter, breaking down pollutants, and keeping us healthy. My research looks at a small part of the whole network of microbial interactions. We're studying corrinoids—vitamin B12 and related cofactors—because they're shared among different microbes. There's interesting structural diversity in corrinoid molecules, and we're figuring out how bacteria make and share these different forms.

In your lab, how do you create an environment that's open and inclusive? I try to create a culture where the lab is a safe space where people from diverse backgrounds can be themselves. Everyone should feel that they belong, that their contributions are valued, and that it's OK to make mistakes, ask questions, and take risks. I also think it's important to be humble in any leadership role. I feel like I'm still just beginning to learn how to be a good mentor, classroom teacher, and group leader.

What changes or improvements in diversity have you seen in science, technology, engineering, and math (STEM) fields? Our department has come a long way in just a few years by prioritizing and opening up conversations about diversity and inclusiveness. It's easier now to speak up about diversity-related issues since we know people care about it. And nationally, there's been a move toward being more inclusive of younger scientists who come from more diverse backgrounds. For example, in the past, only established senior investigators gave talks at the American Society for Microbiology General Meeting, but in recent years, more young scientists are being included.

Britt Glaunsinger is learning how viruses take over cells' gene expression machinery.

What's your best advice for young scientists? Research obviously has its high points—like when you discover something new, get a grant funded, or publish a paper. But those high points are few and far between. There are plenty of low points, too. You can pour your heart and soul into a project that doesn't work out. Grants and papers get rejected. It's important to acknowledge that science can be mentally and emotionally taxing and to have a way of dealing with it. I advise investing in friendships and having hobbies outside of the lab. Right now my favorite hobby is playing with my kids!

Britt Glaunsinger

Virologist
Associate Professor, PMB
Investigator, Howard Hughes Medical Institute

What is your area of research, and what is its potential impact? I study viruses—it fascinates me how such minute entities efficiently take over cells they infect. The genome size of a virus is generally more than a thousand times smaller than ours, but they've evolved to outwit us on a regular basis. My lab is focused on figuring out how viruses take over cells' gene expression machinery and how they repurpose it to make viral genes and proteins. We work on a group of herpes viruses that can cause cancer in people with

compromised immune systems, like AIDS patients. Viruses are excellent teachers of biology, so by studying them, we also learn a lot about how our own cells work.

In your lab, how do you create an environment that's open and inclusive? If you're considering only one perspective that's synonymous with yours, you're losing out on a whole spectrum of intellectual capital and creativity. In a diverse group of people, everyone must have the confidence to voice their ideas, so it's important to create an environment in which everyone's opinions are valued. We also must respect that everyone has different work styles and home commitments, so we need to move away from this bravado mentality that everyone must work 60 hours a week. The number of hours doesn't necessarily equal better output. People do their best work when they're happy.

What changes or improvements in diversity have you seen in STEM fields? In my 10 years at Berkeley, I've seen an increased interest in recruiting diverse candidates and developing tools to identify and support those beyond the traditional demographics. It's also becoming more of an issue at national conferences, where keynote speakers are often still predominantly white men. Now those events will get shamed on social media. People are working to diversify speaker lineups, and one way is to show hard data to scientists—that the program is consistently male-dominated. They can't argue with it. The data doesn't lie!

What's your best advice for young scientists? It's impossible to overestimate the value of being a good communicator in science. Your discoveries will have more impact and you'll get more recognition if you can convince others why your work is important. Strong oral and written communication is the single most important thing besides doing great science.

Chelsea Specht

Plant Organismal Biologist
Professor, PMB and Integrative Biology

What is your area of research, and what is its potential impact? My lab focuses on the evolution of biological diversity, specifically how plants have evolved different forms and functions and how those differences in form have enabled them to diversify in space and time. With the inevitability of climate change, it's becoming necessary for species to adapt to new environments. We can perhaps find ways to breed or engineer crops to adapt to a future of more stressful conditions.

In your lab, how do you create an environment that's open and inclusive? I'm convinced that true excellence only emerges with a fundamentally diverse research and academic team. People open up more, and explain themselves better, when they don't fully expect to understand each other but are eager to learn from one another. There are no assumptions that you're all coming from the same place and so have nothing new to offer. By creating a community built on developing new shared experiences, we can engage with one another and with each other's science at a deeper level.

What changes or improvements in diversity have you seen in STEM fields? In my 20-year career, the main change I've seen is that there do seem to be more senior women in science acting as role models. When I was younger, the senior women had worked so hard to get where they were, their attitude was, "Why should you have it any easier than I did?" We also see the same white men receiving the highest accolades from academic institutions and societies, and that sends the message that "you can be a successful student, but don't expect to become a respected scholar." Women and people of color are overlooked and underestimated, and we need to change that narrative in STEM.

What's your best advice for young scientists? My strongest piece of advice is that young scientists need to actively develop a network of advisers, mentors, peers, colleagues, and collaborators. Insist on developing that early on and use it throughout your career to navigate your desired trajectory. I also think it's important to develop personal networks, families and communities outside of academia. Support from both is necessary to develop your personal passion as a scientist. And you can then take your success in science back to those communities, to be the role model who can inspire the next generation of diverse scholars to pursue scientific careers.

Chelsea Specht studies the evolution of biological diversity.

Mary Wildermuth is studying the growth and reproduction of a pathogen on its host plant.

Mary Wildermuth

Biochemist and Molecular Biologist
Associate Professor, PMB

What is your area of research, and what is its potential impact? My lab explores factors that govern the extent of growth and reproduction of a pathogen on its host plant. One well-known and economically important pathogen we study is the powdery mildew fungus, which only grows and reproduces on living plants. Therefore, we're figuring out what the powdery mildew requires from the plant at each phase of its colonization and growth and how it manipulates the plant to acquire the nutrients it needs while limiting plant defense. Our study of plant-microbe interactions also provides insights into fundamental biological processes of organisms. For example, our work on induced polyploidy, which results in increased cellular DNA content, relates to cancer cell persistence following chemotherapeutic treatment.

In your lab, how do you create an environment that's open and inclusive? I'm promoting our next generation of diverse scientists at every level: in K through 12, through the Be A Scientist program I founded; and in my laboratory, through recruitment, individualized mentoring, and support of diverse undergraduates, graduate students, and postdocs. Through the Biology Scholars Program, CNR's Sponsored Projects for Undergraduate Research, and the campus-wide Undergraduate Research Apprentice Program, I recruit undergraduates to my lab, where they're partnered with more senior lab members and mentored and supported to become independent scientists.

What changes or improvements in diversity have you seen in STEM fields? Over the course of my academic career, I've seen a significant increase in the number of women in STEM fields and a smaller increase in the number from underrepresented groups. However, in recent years, the number of women among STEM faculty seems to have plateaued at levels below their numbers in PhD programs. More work is needed at every level of education to continue to make careers in STEM viable and attractive options for women and people of color.

What's your best advice for young scientists? Do what you love and are passionate about. In the end, it's the scientific questions that should drive you. Choose laboratories with inclusive and positive work environments, which promote collaboration. Scientific research is both challenging and exhilarating—you never know what the outcome will be. When things aren't working, passion and supportive colleagues can keep you from getting discouraged.

WHERE BUSINESS AND SUSTAINABILITY CONVERGE

BS 2014 ENVIRONMENTAL SCIENCES;
ENVIRONMENTAL ECONOMICS AND POLICY

TIFFANY TRAN

For typical food consumers, the first factors to influence a purchasing decision, Tiffany Tran says, are taste and cost. "Sustainability might not be top-of-mind." Tran is determined to change that. In her role as a sustainability analyst at Annie's—a Berkeley-based, socially and environmentally conscious food company—she helps to promote and track consumer education about Annie's initiatives that focus on organic and sustainable farming practices.

By Molly Oleson

PHOTOS: Courtesy of Tiffany Tran

Since 2008, Annie's has partnered with Organic Valley to source organic dairy products. Now, along with its parent company, General Mills, Annie's has announced a new phase in the partnership: the addition of approximately 20 dairy farms and 3,000 acres of organic dairy production over the next three years. Annie's is also part of the U.S. Organic Grain Collaboration, which is working to increase the country's supply of organic grain. The brand responsibly sources the cacao, palm oil, and sugarcane in its products, and animal welfare is a top priority when it comes to using dairy, eggs, and meat.

"At the end of the day, agriculture is one of the biggest contributors to greenhouse gas emissions and climate change," Tran says. "We hope that if we can tackle things from the ground up, then the industry and the economy will head in a direction that results in more positive environmental impacts."

Motivating consumers to buy green

On top of "meeting consumers where they are" with information about Annie's goals and mission, so that they feel good about buying products that protect and enhance the planet, Tran manages the company's responsible-supplier program, leads the development of annual sustainability reports, implements employee initiatives, and aims to reduce the carbon footprint of the brand's headquarters.

"I'm passionate about the intersection of sustainability and business," Tran says, noting that this interest grew out of volunteering with the Berkeley chapter of the nonprofit Net Impact during her third year at Cal. Today, she's co-president of the San Francisco professional chapter, focused on planning events and providing resources for professionals interested in making a positive environmental and social impact both at work and at home.

Tran, a Long Beach, California, native who was attracted to the "forward-thinking" Bay Area, started out in pre-med before deciding in her second year that it wasn't her passion. "I started to think hard about where I wanted to spend most of my time and energy," she says. "I boiled that down to protecting the environment and what I can do to help ensure that this world we live in continues to be beautiful and healthy."

The environmental sciences major fit perfectly, Tran says, because she wanted to be well-grounded in a science background for the environmental work that she hoped to pursue. Once she discovered that she was fond of economics, she went for the double major and "crazily enough" also pursued a minor in sustainable design. A part-time job at the campus's Career Center exposed her to resources available for job-seeking students, and several informational interviews with professionals working in corporate sustainability led to a fascination with the field. Tran began taking business classes at the Haas School of Business, and one was a case-study-based sustainability and business course that she says "drove it home for me."

"Agriculture is one of the biggest contributors to greenhouse gas emissions and climate change."

"I absolutely loved my experience there," Tran says of Cal, emphasizing the unique perspectives of brilliant people from around the world and professors who were experts in their fields. "Many of my Berkeley learnings translated directly to my workplace knowledge."

Positive impacts through agriculture

After graduating, Tran worked in Southern California on the Walt Disney Company's Environmental Policy Team, conducting research and creating guidelines for running an environmentally responsible business. But she was eager to get back to the Bay Area.

Tran says that the corporate social responsibility space has evolved significantly over the last few decades, and that it continues to grow today. Her goal over the next few years is to focus on how companies can make positive environmental impacts through agriculture. "There are many different opportunities to implement more environmentally friendly farming practices," she says.

At 24 years old, Tran has already been honored as one of *GreenBiz's* "30 Under 30" emerging leaders in corporate sustainability. She's passionate about continuing to influence colleagues, business leaders, and the general public. And she's interested in pursuing an MBA down the road to learn more about where sustainability and business can converge.

For now, Tran says, she's dedicated to creating a bigger and better environmental impact. "There's so much more work to be done," she says. "I feel like I'm creating a better future by helping define what it takes to be a responsible business."

Tiffany Tran hangs out with her own bunny mascot at the Annie's headquarters in Berkeley.

Double Legacy

PHOTO: Courtesy of Bill and Lisa Liu

For **Bill and Lisa Liu,** loyalty to your alma mater can be an intergenerational thing. Although neither of them attended the University of California themselves, they got to know the institution through their two sons. James Liu majored in ecology and evolutionary biology at UCLA and then went to UC Davis for veterinary school. **Alex Liu** graduated from the College of Natural Resources with a major in molecular toxicology in 2006. Their parents were so impressed by the quality of education and research within the UC system that they decided to give back to it. Last year, as part of the Berkeley Endowments to Attract and Retain Graduate Students (BEAR GradS) program, they established the William and Lisa Liu Fellowship for Environmental Studies at CNR.

"We're passionate about both the environment and the mission of this public university," says Bill. "The natural world is in a crisis of our own making. Our state and nation face critical problems that demand solutions from the top minds in the country."

Both senior Lius represent, in their heritage, an international diversity not uncommon in the United States. Born in Taiwan, Bill moved to Washington, DC, when his family immigrated to the United States in 1966. Lisa, a third-generation American, was born in El Paso, Texas. Her paternal grandfather emigrated from China in 1912 at the age of 12, and her maternal grandparents came from Guangdong Province in the early 1920s.

The couple, who met in the DC area and married in 1979, personally understand the value of graduate student fellowships. Both earned advanced degrees—he an MBA at the University of Maryland, she a doctorate in cognition and communication from the University of Chicago.

As they raised their young family, the Lius moved around the country, landing in the Bay Area in 1987. After reading a book called *The New Papyrus,* about the emergent medium of CD-ROMs, Bill designed, sourced, and assembled the components to make the first portable CD-ROM drive in his living room, before founding Custom Design Technology that same year. Today, capitalizing on the strengths of his small-business-development experience and fluency in Mandarin, Bill's current company, Silkroad RV, exports recreational vehicles from the United States to China. Lisa developed educational software for 20 years and now works in Saratoga as a librarian for the Santa Clara County Library District.

"We feel strongly that climate change, conservation, and sustainability are the world's most pressing problems," says Lisa. "We also emphatically believe that graduate education is vital—not only for deserving students but also as part of a larger research program focused on the complicated problems facing our state and nation. We're so fortunate to have these top-notch scientists within the UC system, and we can't think of a better way to use our resources than to endow a CNR graduate fellowship at Berkeley. Imagine what these students could do if they all had fellowships."

— KIRSTEN MICKELWAIT

The Generosity of BEAR GradS

The Lius made their gift as part of a matching-gift program launched by Berkeley's Graduate Division in 2015. The Berkeley Endowments to Attract and Retain Graduate Students (BEAR GradS) program provides a match of $500,000 for donor gifts of $500,000. Matches are made possible through generous bequests from the estates of **Helene I. Cantor '35, William V. Power '30,** and **Raymond H. Berner.** The Liu gift is the second such fund established with CNR.

CNR invites parents to consider making a generous gift to create a fellowship or otherwise support the student experience.

The Origin of the Honey Bee | Photo by Alex Wild

A worker honey bee (*Apis mellifera*), covered in dandelion pollen. Environmental science, policy, and management professor **Neil Tsutsui** and UC Davis researchers Julie Cridland and Santiago Ramírez recently used whole-genome sequence data to reconstruct the evolutionary history of this important pollinator in its native range. They found that the honey bee likely first appeared in northern Africa and the Middle East, then colonized Europe in two separate waves.

Descendants from one of these waves constitute nearly all of our managed bees for agriculture, honey, and other hive products. Published this spring in the journal *Genome Biology and Evolution,* the research reconciles previous, contradictory scenarios for the origin of modern honey bees and will assist future research on how bees may adapt to climate change, disease, and other threats.

This research was funded by the Gordon and Betty Moore Foundation through a grant to the Berkeley Initiative for Global Change Biology.