



Jasper Ridge Biological Preserve

Annual Report 2015–16

OUR MISSION

Contributing to the understanding of Earth's natural systems through research, education, and protection of the preserve's resources.



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Front Cover: A California newt (*Taricha torosa*) migrates to new territory on a rainy day.

Inside Cover: A tiny beetle feeds on pollen from a Blue-eyed grass flower (*Sisyrinchium bellum*).

Right: Leaves of Valley oak (*Quercus lobata*) displaying fall colors.



FROM THE OUTGOING FACULTY DIRECTOR

CHRIS FIELD, PhD '81, Professor and Director, Stanford Woods Institute for the Environment

September 2016 was the 40th anniversary of my first visit to Jasper Ridge. I still remember my amazement, as a beginning graduate student, that all of this would be available to me, not just the spectacular landscapes, but also the history of magnificent science. That September, I found a gardener's cottage near the base of Old La Honda Road, and I spent the next five years going some days to campus, but almost every day to Jasper Ridge. As a graduate student, perhaps my biggest claim to fame was my essentially nonstop case of poison oak. While I never got used to poison oak and certainly didn't develop anything like immunity, the poison oak was nothing compared to the license to build my own science empire, even if it was limited to a scruffy patch of chaparral around the structure euphemistically called the Hillside Lab.



I have no doubt that, as a graduate student, Jasper Ridge convinced me to choose a path in research. Working at Jasper Ridge meant that I was walking the same landscapes as the scientists defining the frontiers of ecology. It meant that, in a single day, I could finish an instrument, take it to the field, break it, and still participate in a great seminar in the afternoon. It meant that I could try things again and again, and again and again, until I finally got them working after just another couple of attempts. It meant tapping into a vibrant scientific community, where we all apprenticed to each other. In an era when most of the ecophysiology addressed one or a few species, I really became a professional ecologist helping fellow students with studies of nutrient cycles, phenology,

pollination, and drought adaptations on Nona's *Hemizonia*, Annie's *Linanthus*, and Bill's *Rhamnus* (now *Leptosiphon* and *Frangula*!).

I feel incredibly privileged to be celebrating 40 years of association with Jasper Ridge. But I feel even more excited that Jasper Ridge continues to work its magic, helping generation after generation of students become professional researchers. In my eleven years as faculty director, it has also been immensely rewarding to see the impact of the preserve on thousands of students and on the local community, with the unique Jasper Ridge docents providing a constant bridge and support network.

In the last 40 years, Jasper Ridge has changed in many ways. Jasper Ridge science is detailed in a lot more publications. And the facilities are a lot better. But it is still the same in many ways. Biking up that last hill on Sand Hill Road, coming from campus, is still a pain. More important, the possibilities for discovery and the opportunities to transition from student to scientist are as ripe as ever. And of course, the incomparable Jasper Ridge staff—Brooke, Cary, Cindy, Jeff, Nona, Siri, Steve, and Trevor (and in previous years, Alan, Alison, Carolyn, Justin, Leonard, Monika, Philippe, Rebecca, and others)—always make things happen like there really was a plan.

I will continue to be involved with Jasper Ridge research. I will definitely miss the sense of helping steward one of Stanford's and the scientific community's greatest assets. But I am also excited to see a strong operation transition to a new era. Liz and Tony's sophisticated vision and infectious enthusiasm assure a bright future.



FROM THE INCOMING FACULTY DIRECTOR

ELIZABETH HADLY, PhD, Paul S. & Billie Achilles Professor of Environmental Biology

My love is fieldwork, whether working on tigers, pikas, rodents, bats, birds, reptiles, amphibians, mapping geology, or excavating paleontological sites. So when I was asked if I was interested in becoming JRBP's Faculty Director, it did not take much convincing. In my capacity as Professor of Biology, I had supervised student projects at JRBP, notably on bat acoustics and sampling the small-mammal fauna through collecting bone-laden raptor pellets, so I was no stranger to the preserve. Those experiences also familiarized me with some of the ground-breaking work that was (and is) ongoing by the Stanford faculty, students, the JRBP docent community, and researchers and educators from throughout the world. These past interactions at JRBP made it clear that the preserve will play a critical role in deciding whether nature stays healthy in the coming decades. In fact, that's what sealed the deal for me: developing strategies to keep species and ecosystems vibrant under today's incredibly rapid global change has been a key focus of my research.



Particularly exciting to me at JRBP is the opportunity to blend my deep commitment to fieldwork and nature with two other responsibilities I feel equally deeply. The first is teaching the next generation of students how to navigate and improve the global society; the second is science communication. Through my three-year tenure as Senior Associate Vice Provost for Undergraduate Education, I saw firsthand how emplacing effective educational programs at Stanford can have the downstream effect of changing the world—our students are the best in the world and they come to us eager to effect change for the good.

Nowhere is this more needed than in conservation of nature and the intertwined issues of climate change, population pressures, loss of ecosystem services, and extinction. JRBP is exceptionally poised to fill this need by virtue of the strong education and outreach programs already in place, and the excitement and support already shown by the JRBP community.

My commitment to science communication comes from working with policy makers at the local through international levels over the past few years, and the realization that providing actionable knowledge is a different skill than writing a scientific report. While the top-down approach is important, perhaps even more important is communicating actionable scientific discoveries at the grass-roots level, so that policy makers have the support of their constituents. Here, too, JRBP offers many opportunities, with the potential to develop a new generation of science communicators using venues that non-scientists respond to, ranging from the arts, to the humanities, to the engineering community.

When I took the Faculty Director baton from Chris Field on September 1, it was with a sense of admiration for all he has accomplished at JRBP and in the world at large, and a feeling of deep honor that this crown jewel of Stanford would now be my responsibility. Chris, Philippe Cohen as Executive Director, and the incredible JRBP staff have already planted the seeds needed to make JRBP pivotal in international nature conservation, education, and science communication. As we go into the next few decades of uncharted environmental territory, I'm looking forward to working with the entire JRBP community to adapt to the future while also saving what we hold dear.



FROM THE EXECUTIVE DIRECTOR

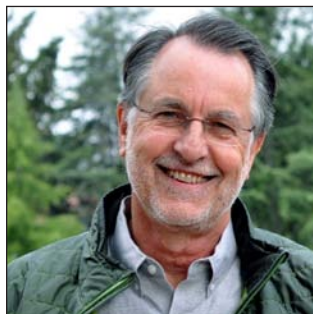
ANTHONY D. BARNOSKY, PhD

The redwood grove on Trail 1 was one of the first places that Philippe Cohen took me when I dropped by to ask him what it was like being Executive Director. Two things he said stuck in my mind. The first was that he had intended to sit in that redwood grove and think great thoughts when he started the job, but interacting with all the exceptional people and programs at JRBP just kept him too busy. The second was that being Executive Director at Jasper Ridge was the best job in the world.

Just a few months into the job, I'm seeing the truth in both of those statements. Even before I started, I knew that the research and education going on at JRBP were world-class. Through my past work as a professor and research scientist involved in discovering and communicating how natural ecosystems respond to unusual environmental changes, I had also had the good fortune to cross paths with some of the faculty and staff, whose talents became even more apparent once I came on board.

What I hadn't known, and am enthusiastically discovering day by day, is the multi-faceted help offered by the greater JRBP community, who so willingly lend a hand and bring so much expertise. Last year, volunteers worked more than 18,000 hours! I'm looking forward to meeting many more of you.

A notable milestone this year, of course, was Philippe's retirement. His accomplishments at JRBP were many, and it's fitting that they were recognized by establishment of The Philippe S. Cohen Graduate



Fellowship, created through the generosity of Jean Lane and Lysbeth W. Anderson to provide financial support for graduate students whose research is conducted at or benefits JRBP. Also in his honor, the Jasper Ridge Director's Fund was renamed the Philippe S. Cohen Jasper Ridge Director's Fund. Originally created through the kindness of Lysbeth W. Anderson and John Working with the hope that it would receive additional contributions over the years, the fund continues to be augmented by many other generous donors, increasing the resources it provides for JRBP. We greatly appreciate all of our supporters, including Philippe for his many years at the helm!

Special thanks are also due to outgoing Faculty Director Chris Field, under whose leadership the academic programs have flourished, and to Nona Chiariello, who guided JRBP with diligence and care in the interim between Philippe's retirement and my first day.

Going forward, JRBP faces challenges, for example, Searsville Dam. The Steering Committee's recommendations are now being evaluated by local, state, and federal stakeholders, and intensive modeling is underway to more fully understand the impacts of various options on the watershed. At the same time, global changes now reaching into JRBP will likely intensify: for instance, climate change is increasing drought intensity and fire frequency, and in the near future may eliminate some species' habitats while creating new places for others to thrive.

These challenges offer opportunities by stimulating new collaborations and approaches. Already moving forward is a revitalized linkage of JRBP with nine other California agencies that together comprise

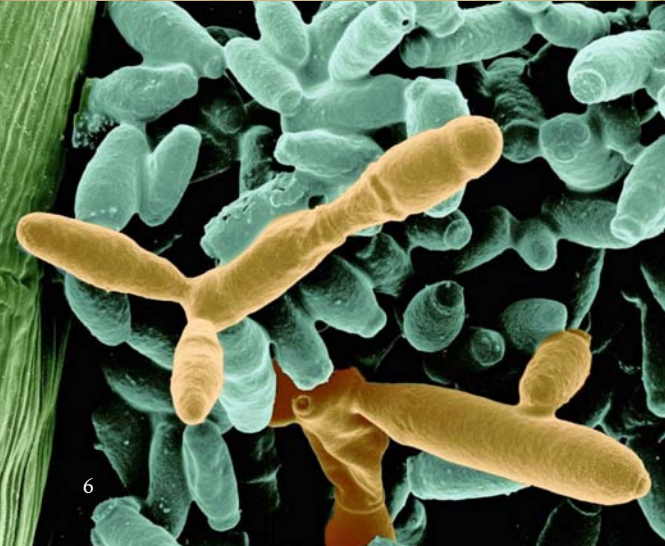


the Golden Gate Biosphere, a globally important conservation region recognized by UNESCO under the Man and the Biosphere Programme. Such interactions with broader initiatives enhance ways for JRBP to incubate cutting-edge science and cross-disciplinary communication, so critical in keeping ecosystems and species healthy as the world continues to change rapidly in unprecedented ways.

For me, navigating this new landscape with the wonderful JRBP community, along with our new Faculty Director Liz Hadly, is what makes this the best job in the world. I do hope, though, that I find some time for that redwood grove.

Opposite: Exemplifying the challenges and opportunities at JRBP is Searsville Reservoir, with the Leslie Shao-ming Sun Field Station in the background.





RESEARCH

NONA CHIARIELLO, PhD '81

“Without any question, Jasper Ridge is the most important laboratory Stanford has. It will be infinitely valuable (in) 100 years ... when virtually every other laboratory will be passé and will have disappeared.” —Paul Ehrlich, 2012

The 2015–16 academic year was one of intense, productive, and diverse research, and included several new studies that would have been unimaginable in the past. Sixty-two studies were carried out by members of eight Stanford departments and 24 other institutions, six of which are outside the U.S. The year’s research publications amounted to twenty-two journal papers, four dissertations, and four honors theses in three undergraduate majors. Volunteers and staff completed a comprehensive database of JRBP maps and an updated list of vascular plants, bryophytes, and lichens, more than 950 taxa in all.

The number of biology faculty conducting research at JRBP has never been greater. Deborah Gordon’s study of the Argentine ant invasion completed its 24th year and added another species to their records, a cryptic army ant. Rodolfo Dirzo’s research on trophic interactions expanded with a new collaboration to examine bobcat populations through genetic analysis of their scat. The global change experiment is in a synthesis phase, and Chris Field and colleagues produced nearly a third of JRBP’s publications this year, including a 17-year analysis of primary production. And there is a critical mass of cutting-edge research on microbial diversity and interactions, including

Tad Fukami’s ongoing work on microbes in *Mimulus* nectar, Erin Mordecai’s research on fungal pathogens, and Kabir Peay’s studies of soil microbes.

The biology department is far from alone. There are ongoing studies in archaeology, earth system science, engineering, and geophysics. In addition to their fundamental significance, many of these studies will contribute to decisions on the future of Searsville Dam, including long-term ground water monitoring by David Freyberg, and Laura Jones’s work on the region’s history and pre-history. One of Stanford’s youngest departments, bioengineering, has started three studies, including the first study of tardigrades, a rather amazing animal phylum found in mosses, lichens, and soil. There were also firsts in the role of arts: an art–engineering collaboration in which an array of wind sensors at Jasper Ridge controlled a lighting array in the McMurtry Building, and the first dissertation in theatre and performance art that includes work at JRBP.

Whatever their discipline, each researcher sees a slightly different slice of the preserve. On the following pages we feature a small sample of their perspectives—wetlands pre-Searsville Dam versus the present; grassland studies of global change and fungal pathogens; and woodland studies of western leatherwood and dusky-footed woodrats. An important take-home message from these essays is how the significance of individual studies is strengthened by the interconnections among them. For example, woodrats and leatherwood illustrate the conservation dilemma of one designated vulnerable species impacting the persistence of another.

Documenting, understanding, and conserving biodiversity remain as vital to our research mission as ever. Liz Hadly and Tony Barnosky bring a passionate global vision for embarking on a new chapter in meeting this challenge.

Top: A rare species of army ant, *Neivamyrmex californicus*; no live individuals were detected in the Argentine ant survey until its 24th year.

Middle: A tardigrade, 0.75 mm long, collected by Ricky Cordova and Eda Benites from lichen on a fallen tree limb.

Bottom: Scanning electron micrograph of nectar yeast *Metschnikowia* on *Mimulus*, from studies by Manpreet Dhali and Tad Fukami.

The historical ecology of lower Corte Madera Creek

LAURA JONES, MA '85, PhD '91, Director, Heritage Services & University Archaeologist

Before Hetch Hetchy, there was Searsville Dam. Built in 1892 to supply the burgeoning city of San Francisco, the reservoir was never used as a drinking water supply. Instead, it became a recreation area, and eventually part of JRBP. A century's worth of deposited sediment helped create a rich upstream wetland habitat for bird and bat species, but also nearly filled the reservoir. As you can see in the map at lower right, the extent of open water now is less than a quarter of its maximum in 1892.

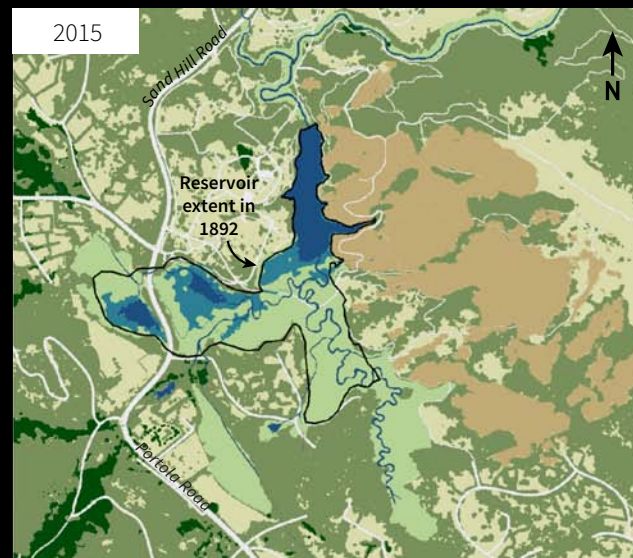
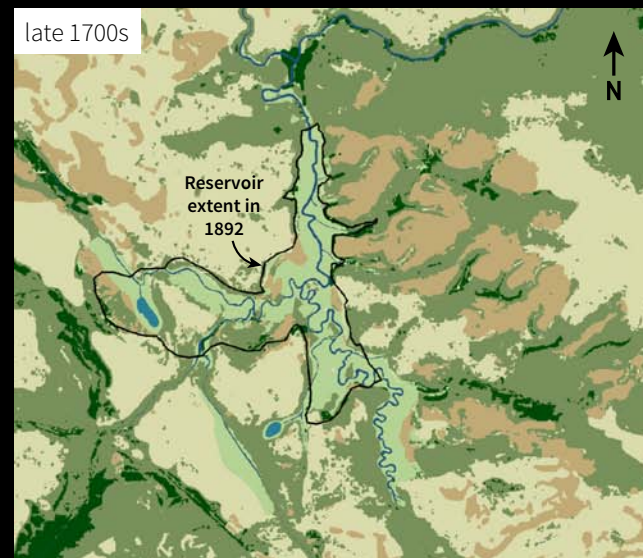
Planning is underway to undo the sedimentation. Stanford University is evaluating the feasibility of creating an orifice at the base of the dam and allowing fine sediments to flush to the bay, permitting a return to a riparian corridor. As part of the planning, I assembled a multidisciplinary team* to determine, as best we could, what that riparian corridor and surrounding vegetation looked like a century before the dam. We combined in-depth historical research

with current and historical geospatial data to predict the likelihood of land cover for each type of vegetation in the late 1700s. The key document that enabled this approach was a detailed 1890 topographic survey, from which we could identify slope and aspect and other landscape properties. By evaluating the present-day distribution of vegetation types in similar sites on the eastern slopes of the Santa Cruz Mountains, we determined where each vegetation type might have existed. We then analyzed the best available historical information, such as explorers' accounts, maps, photos, etc., to weight the likelihood of vegetation types relative to one another at any given spot, based on various weighting scenarios. Our final map, at lower left, reflects the best correspondence with all these kinds of information.

Comparing past and present vegetation in the two maps below, you'll notice that west of the reservoir, the distribution of redwood forest looks similar for

the late 1700s and 2015, whereas north and east of the reservoir, most of the redwood stands of the late 1700s have been replaced in 2015 by chaparral or oak woodland. Another significant feature in our analysis is that the major creek corridors that were inundated by the reservoir had previously been riparian forest, much as the area upstream of open water is today. Native American practices, including use of fire to encourage grass seed production and the management of nut crops, were reflected in early explorer accounts of more widely spaced trees, and more grassland than is present today. On the early map this accounts for the greater extent of the grasslands, and slight reduction in chaparral areas.

Our analysis was focused on the past but is relevant to the future. Although many factors will determine the sustainability of turning the reservoir into a riparian corridor, including changes in land-use and climate, history is surely one important guide.



*The Center for Spatial Analysis at Stanford (CESTA) team included cartographer Erik Steiner, who built the map model, biologist Maria Santos who performed the land suitability analysis, and research assistant Matthew Walter. Members of the Searsville Study team also participated, including biologist Alan Launer, civil engineer Tom Zigterman, geographer Philippe Cohen, and hydrologist Jonathan Owens. Special thanks to historian Julie Cain, John Rawlings and Nona Chiariello who contributed their deep knowledge of the history and landscape of the Preserve.



Dusky-footed woodrats: ecosystem engineers

BENJAMIN BRAVO, '16, Earth Systems

The dusky-footed woodrat (*Neotoma fuscipes*) is a large rodent that occupies many of the vegetation communities of Jasper Ridge. They have been regarded as “ecosystem engineers” because they build houses a meter tall made of twigs, branches, and leaves, thus influencing vegetation growth and composition. When abandoned, the houses can be used by a variety of other animals, thus influencing faunal composition as well. Understanding the ecology of dusky-footed woodrats therefore helps in understanding the interactions of species in the many Jasper Ridge communities in which they are found.

Learning more about woodrat ecology was the focus of my honors thesis research, which began as a project for *BIO 105*. Over the course of one spring, I found more than 350 woodrat houses along 13 major trails. In order to dig deeper into the habitat requirements and ecology of the dusky-footed woodrat, I expanded my initial research methods to include off-trail transects and to observe woodrat activity via camera traps



Dusky-footed woodrat house.

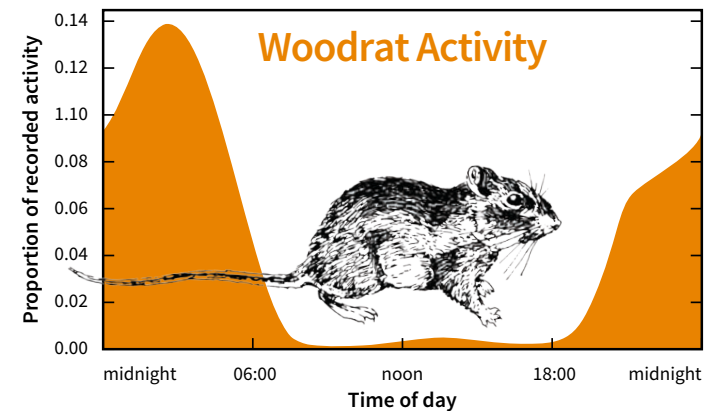
outside their houses. I conducted 50 transects in five plant communities: broadleaf forest, chaparral, non-serpentine grassland, riparian woodland, and scrubland. I also characterized the microhabitats of houses.

I found that the highest density of woodrat houses is in the riparian woodland, and that the density is somewhat lower but similar in chaparral, scrubland, and broadleaf forest. On a microhabitat scale, woodrats prefer areas that have more logs, but shrub and tree density do not seem to make any difference. However, their preference made a difference to me. Transects located in riparian, chaparral, and scrubland were a physically demanding adventure. I climbed over logs, crawled under dense shrub mats, and pushed my way through thickets of nettle and poison oak, all for the sake of collecting data that accurately represented the woodrat's environment.

I also studied activity patterns of dusky-footed woodrats and other riparian animals near occupied and unoccupied woodrat houses. I set up cameras near 10 woodrat houses in the riparian woodland and monitored woodrat and other animal activity for five weeks. I found that larger houses are more likely to have visitations by woodrats than smaller houses. Woodrats are predominantly nocturnal with peak activity at around 2:00 a.m. The most frequent visitors to woodrat houses are California mice, birds, and rabbits, but only the California mouse has an activity pattern that overlaps substantially with that of the woodrat. My camera traps also recorded visits to woodrat houses by deer, bobcats, mountain lions, skunks, squirrels, opossums, and lizards.



Crawling through a thicket to survey the density of logs, shrubs, and trees in riparian woodland.



Daily activity pattern of woodrats determined from camera-trap records over a five-week period. Raw data were smoothed using a statistical procedure, kernel density estimation.

Future research at Jasper Ridge should include tracking woodrats with radio collars to better understand house occupancy and to determine how far woodrats travel from their houses and into other vegetation communities, and camera traps to better understand the biotic relationships between woodrats and other animals. I hope to continue pursuing research on woodrat behavior, particularly to understand how woodrats might change their daily activities in response to the presence of other animals near their houses.

Jasper Ridge: a leatherwood laboratory

BILL GRAVES, Associate Dean and Professor, Iowa State University

Rain returns. Buds swell. Delicate yellow flowers appear like ornaments on an otherwise quiescent landscape. The leatherwoods of Jasper Ridge signal seasonal change and serve as harbingers of the hydration and growth that will follow in the floristic community. Is the first flower of the season spotted closer to Halloween, Thanksgiving, or New Year's Eve? Does peak blooming seem early or late? Are shrubs flowering in unison or on dissimilar schedules? These questions of phenology, the cyclic timing of seasonal development, are discussed among members of the Jasper Ridge community each year. My research has been influenced by these conversations as I've sought to determine what governs the phenology of leatherwood, to model variation in flowering time, and to understand the implications of that variation.

Leatherwoods, which belong to the genus *Dirca*, contribute strongly to our floristic diversity; in fact, *Dirca* is the only genus of its plant family indigenous to the United States. In California, *Dirca occidentalis* is found only in limited populations in six Bay Area counties. Its narrow distribution raises the possibility that leatherwood depends on an unusual set of

environmental factors to persist and thus may be especially vulnerable to climate change. Moreover, observers have noted populations in decline and have stated that, despite prolific flowering, seed-bearing fruits rarely form. Some of my earliest work with leatherwood required finding shrubs throughout the Bay Area, from Bodega Bay to Orinda to Stevens Creek. Although the main conclusion I published from that work was that populations are highly isolated from one another genetically, my trekking from population to population to collect DNA led me to believe that Jasper Ridge supports the greatest prevalence of leatherwood in the Bay Area. How fortunate for me that leatherwood is particularly abundant at a preserve devoted to conservation, discovery, and education, a magnet for a community of scholars who have been so welcoming to a leatherwood enthusiast from the Midwest.

To me, Jasper Ridge is a leatherwood laboratory where, so far, I have collected data demonstrating that not only do geographically disparate individuals within the preserve bloom on different schedules, but also that schedules matter. The likelihood that a flower will result in a fruit, and thus a seed, depends on when the flower forms, and many flowers form when the probability of fruit set is very low. I've also concluded that new plants of leatherwood far more often result from seed germination than from asexual means. Knowing that viable seeds likely are required for the continued existence of leatherwood, and that seed set may be rare and strongly influenced by climatic factors that govern phenology, I have embarked on a long-term phenological and life-history analysis.

I'm now focused on 100 individuals selected in 2011 from throughout the preserve. I collect data on these plants annually on the same nine days



of the year, from early November to early April. I document each plant's phenological status and tag 48 flowers per plant to track how many of those subsequently become a fruit. Floral phenology, fruit set, and vegetative growth are being modeled with data on temperature and precipitation. This will enable predicting the reproductive capacity of leatherwood as the climate changes. I'm also documenting biotic interactions, including pollinator activity and damage by dusky-footed woodrats. These nocturnal rodents seem to seek out leatherwood for harvesting its strong, flexible bark or entire stem sections, sometimes removing high percentages of total stem tissue. I am recording the frequency and timing of these events and how shrubs that have been preyed upon respond. Lastly, I am documenting apparent mortality, which, in some cases, must be re-characterized as resurrection after new shoots arise from belowground. Each year that these methods are replicated strengthens the dataset and thus our potential to understand leatherwood as a botanically unique and environmentally sensitive component of several plant communities at Jasper Ridge.

Top-right: *Dirca occidentalis* in bloom.

Bottom-left: Leatherwood with bark and branches removed, typical of damage suspected to be caused by woodrats.

Bottom-right: *Dirca occidentalis* being visited by a honeybee.



Impacts of disease on grassland plant communities

ERIN MORDECAI, Assistant Professor, Biology

California's grasslands are paradoxically rich in native and endemic species yet heavily invaded by exotic Eurasian grasses. On serpentine soils, where low nutrient concentrations and toxic heavy metals inhibit growth of the poorly-adapted exotic grasses, we see relict communities of California natives—from poppies to goldfields to purple needle grass—flourishing. Yet under more forgiving growing conditions we see only a few native plant species—mostly perennial bunchgrasses—able to tolerate the exotic grass competition.

When California native grasses *Stipa pulchra* (purple needle grass) and *Elymus glaucus* (blue wild-rye) grow alongside exotic annual grasses, they not only compete for water, light, and nutrients but also wage biological warfare through shared fungal pathogens. These fungi can infect leaves, seeds, and roots and cause symptoms ranging from plant acne to death. How do these shared pathogens affect the outcome of competition between California's native

and exotic grasses? Do the pathogens help native grasses fend off exotics, or do they help the exotics suppress native grasses? The only way to find out is to experimentally expose the grasses to competition and shared pathogens and track the consequences.



"Black Fingers of Death"
on seeds of ripgut grass.

If you've walked by the silt fence containing our experiment, near the Sun Field Station parking lot, you've probably noticed that measuring competition and pathogen infection is a very silly business. The tools of the trade range from plastic forks to toothpicks to spray-painted bamboo stakes. With these tools, we track the fates of individual grasses—

when they germinate, how long they survive, which pathogens infect them and how severe the damage is, and ultimately, if they're lucky, how many seeds they produce. We've found that *Avena barbata* (slender wild oat), *Bromus hordeaceus* (soft chess), *Bromus diandrus* (ripgut grass), *Elymus glaucus*, and *Stipa pulchra* share a remarkable portion of their fungal pathogens. These pathogens are exacting a heavy cost, which sometimes varies by plant species. One of the most dramatic examples is our favorite fungal pathogen—we call it Black Fingers of Death—which killed over 50% of *A. barbata* seeds buried in mesh seed bags. Seedlings of all five species that were infected with fungal pathogens were 40% more likely to die the next week than those without pathogen damage. In the spring, our fungicide treatments reduced fungal damage and increased seed production across species. How do all these costs of infection affect plant populations in the long term? We will find out using mathematical models built from the data we have collected.

The Jasper Ridge Global Change Experiment, from 1997 to 2016

CHRIS FIELD, PhD '81, Professor and Director, Stanford Woods Institute for the Environment

Predicting ecosystem responses to climate change is a very complex challenge. On one hand, predicting the climate itself is a tall order, especially the nature and frequency of extreme events that can reset ecosystems for long periods. On the other hand, ecosystems respond through a myriad of mechanisms and interactions that are difficult to trace.

Beginning in 1997, Hal Mooney, Nona Chiariello, and I set out to tame this complexity by embarking on the Jasper Ridge Global Change Experiment (JRGCE). We chose California grasslands as a model ecosystem for understanding ecosystem processes everywhere, analogous to fruit flies for population genetics or *E. coli* for molecular biology. We had high hopes, but I can't say we expected the JRGCE to become the longest running, best replicated, most multi-factor global-change experiment at the ecosystem scale.

Over almost two decades we have had dozens of participants, five different funders, some of JRBP's wettest years and some of its driest, a fire that started without warning, and a fire that took three years to

plan. Twice we ratcheted up the warming treatment to get closer to the temperature expected in the next century.

The study has yielded many significant results. Warming accelerated plant development, resulting in earlier flowering, senescence and death. This tended to leave untapped moisture in the soil, leading to an outcome we hadn't predicted: in summer, the soil was wetter in warmed plots than ambient, despite greater warming-driven evaporation. Plant growth was stimulated by increased nitrogen deposition, especially for the weediest species. The year following each fire was the only time we saw real evidence of increased total yearly growth (net primary production, or NPP) under elevated CO₂, but there was also more CO₂ released from the soil. These are examples of results from more than 65 publications with more than 30 lead authors.

One thing we did not observe was a persistent change in the plant community as a result of any treatment. Because the plants are mostly annuals, the community

in each plot can "reboot" each year as a function of weather conditions acting on the previous year's seed set and whatever seeds disperse into the plot. In a new paper led by postdoctoral fellow Kai Zhu, we took advantage of this property by viewing the experiment's 16 treatment combinations and 17 years of distinct weather as 16 x 17 or 272 possible future scenarios, each experienced by 8 replicate plots in the experiment. We found that across all observed combinations of temperature, precipitation, atmospheric carbon dioxide, and nitrogen pollution, NPP was highest under historic average conditions. Very different conditions, such as those expected with climate change, decreased NPP. We presented these results as a multidimensional response surface in which the peaks and valleys of NPP are mapped relative to continuous variation in temperature and precipitation, unlike two-level "ambient versus treatment" plots. With this paper, the concept of a model ecosystem proves its value, with patterns that can inform science, policy, and conservation. We are continuing to explore the JRGCE's results in conjunction with author teams from experiments around the world.



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TECHNOLOGY

Camera-trap photo species tagging project

TREVOR HÉBERT

“The camera-trapping effort opens a window on the Jasper Ridge world I will mostly never see ... a mountain lion on a stroll, a bobcat bringing home dinner, a bat revealing its mammalian bone structure. Where are these ghosts caught by the cameras?” —Jane Moss

As the Academic Technology Specialist at Jasper Ridge, I’ve been operating an array of motion-activated camera traps at the preserve since 2009. The project has provided a fascinating glimpse into the hidden lives of Jasper Ridge’s wildlife, through remarkable photos of animals that humans rarely see at the preserve—such as mountain lions, gray foxes, and even a badger.

Wireless technology allowed me to develop an automated system for remotely downloading, archiving, and organizing the camera-trap photos nearly as fast as the animals could trigger the cameras—a significant advance over many camera-trapping projects, which typically require repeated visits to cameras to download data manually. At Jasper Ridge, twenty-four hours a day, seven days a week, 365 days a year, the photos have been coming in, now totaling over 150,000 images. Because the cameras have been continuously operating in the same locations for so many years, the extracted data are immensely valuable in revealing significant longer-term trends in wildlife populations at the preserve.

In order for researchers to conduct comprehensive analyses, we needed a way to identify the animal

in each photo and store that information in a relational database. The Jasper Ridge camera-trap photos presented two specific challenges for data analysis and species tagging. First, the cameras use a non-standard metadata system, so the information such as timestamp and camera attributes stored with each photo could not be easily extracted using off-the-shelf photo organizing software applications. Second, while some progress has been made with computerized recognition of animals in photos, the technology is imperfect, and still requires extensive error-checking and manual identification by people.

To get around the problem of non-standard metadata, I developed a custom application to extract the metadata from each photo and store the information in a database. To facilitate species identification, I linked the photos and metadata database to a simple web-browser-based application that allows volunteers to quickly and easily view each image and indicate which species of animal was photographed. The species-tagged data can then be downloaded for further analysis. I had no idea what level of interest this project would generate, but soon after posting a request for volunteers on the Jasper Ridge email list, I had 10 enthusiastic taggers who, in just a few months, have species-tagged over 50,000 photos.

While I expected that the tagging application would be efficient, I was pleasantly surprised at how much the volunteers enjoyed the work and the extent to which it deepened their appreciation of Jasper Ridge. The next step is to develop a public interface that will allow users to browse and search all the photos by keyword. I expect to complete this in the coming year.



A camera-trap photo of a Red-tailed hawk (*Buteo jamaicensis*).

Volunteers

SHARON BRAUMAN

BENJAMIN BRAVO '16

ALICE CUMMINGS

BOB DODGE

LINDA ELKIND

ALIX MARDUEL

SONNY MENCHER

JANE MOSS

MARGUERITE STEVENS

TAY VANDERLIP '80

Opposite: Mountain lion (*Puma concolor*) mother and cub.

“Jasper Ridge has a rich nightlife of large-mammal activity that most humans are unaware of, and it makes me wonder about the Ridge’s setting and its importance to the persistence of large-mammal populations in the region.”

—Tay Vanderlip



EDUCATION

CINDY WILBER

Education at Jasper Ridge means a lot of things to a lot of people and I love the diversity that brings to my job. Every day is different but the thrill of watching teaching and learning is always what makes it all worthwhile.

The 2015–16 academic year delivered hard work, inspired ideas and more with Stanford University students as well as students from other colleges and universities, teachers from all academic levels and the energy and joy of our K–12 collaborating students.

This year Richard Nevle PhD '95, Deputy Director, Earth Systems Program, School of Earth, Energy & Environmental Sciences, has shared his teaching (and learning) experiences with *EARTHSYS 249: Wild Writing* at Jasper Ridge. Students Amy Kim '16, Albert Wandui '17 and Ken Qin '16 have also shared with us their reflections on teaching and learning at the preserve, Stanford, and beyond.

And, once again heartfelt thanks to all in the Jasper Ridge community for their generosity, talent and commitment that makes the JRBP education program possible.



Wild writing at Jasper Ridge

RICHARD J. NEVLE, PhD '95, Deputy Director, Earth Systems Program

On a bright, blue Saturday morning last April, I set out with my colleague, Emily Polk, and a dozen of our students on a walk toward Jasper Ridge's northern boundary. We'd begun the morning looking out across Searsville Reservoir, telling the story of the preserve, moving from deep time to its tapestry of human history. As students immersed themselves in a rarely accessed part of the Stanford campus, they encountered a wild relict of the landscape that is both bedrock and cradle to the university, a place of stories, curiosity, and sustenance. On departing from the reservoir, I encouraged students to consider the threads of their own stories woven into the fabric of the land. We arrived at the redwood fairy ring and sat in a circle beneath the trees, quieting ourselves in meditation as the sounds of the forest sifted through the branches. A great horned owl hooted from the shadows. A trio of ravens cawed from the redwoods' limbs. The San Francisquito Creek sang from its bed of restive stones. Emily concluded our meditation with a poem by Wendell Berry, *The Peace of Wild Things*, in which Berry describes a vivid encounter with the solacing grace of the natural world. Students reflected on their own encounters with such grace, filling the pages of their journals. The music of Jasper Ridge purred its way into their words.

I recall that cool April morning at Jasper Ridge as an especially powerful moment in an environmental writing class, *EARTHSYS 249: Wild Writing*, that Emily and I taught for the first time last spring. The prior winter, we had labored to design a class that would develop students' writing skills and encourage them



"I dream in nature. I dream of a place where music and nature feed each other, where pianos grow stoic like oak trees in fields of green, the massive frames hanging like low branches covered in lichen and moss."

— Makulamy Alexander-Hills '16

to use the written word for environmental advocacy. As I reflected on the beauty and power of the words students shared with us beneath the redwoods, it struck me that our plans were actually working.

Students came into *Wild Writing* well acquainted with the social-environmental challenges threatening Earth's life-support systems. We aspired to help them grow more adept at communicating these

challenges in ways that could help move and inspire others to action. Our teaching efforts and our students' dedication came to fruition in their final essays. Their writing passionately advocated for protection of the natural world and for our place in it, often through rich narratives that conveyed wilderness as a provider of refuge and solace.

Along with practicing writing, we explored and analyzed numerous works from the canon of American nature and environmental writing. This canon is in the midst of metamorphosis as diverse writers—such as Camille Dungy, Robin Wall Kimmerer, and Lauret Savoy—reimagine and revitalize how we think about environmentalism and our place in the natural world. These writers, as they stand on the shoulders of the likes of John Muir



The Ring-necked snake, Diadophis punctatus, is a harmless species of colubrid snake found at Jasper Ridge. Typically their diet consists of slugs, earthworms and small salamanders.

and Aldo Leopold, challenge and see beyond their predecessors' iconic visions. As students explored the broad, evolving territory mapped by these writers, they discovered spaces for their own voices.

Jasper Ridge has long served the Stanford community as a center for scientific research and environmental education. As Emily and I discovered last spring, the preserve also provides an idyllic classroom, one without walls or windows, for engaging students in the discipline of writing in wild places. In writing at Jasper Ridge, students can enter into a singular grace—their words ally with nature in an act of co-creation that sings out into the world, inspiring protection of what wildness remains.

Growing up, I thought the one profession I would never pursue was teaching. Always the eager student, I could never quite get a handle on how my middle and high school teachers did the impossible, each day squeezing information into a half rowdy, half asleep group of adolescents. I dreamed instead of studying international relations and bringing peace to the Middle East or designing buildings as an accomplished architect.

As a Stanford freshman, I fell face first into the hectic array of schoolwork and extra-curricular activities. However, these abundant opportunities soon gave way to sleepless nights with only my problem sets, essay prompts, and jugs of caffeinated beverage to keep me company. It was in this state that I entered the Jasper Ridge docent course. Our weekly class up at Jasper Ridge was a serene escape from main campus. The wisps of *Ramalina* lichen hanging from buckeye trees and the constant chattering of squirrels and birds—the sheer peace yet aliveness



of the place—became a haven where I could center and revitalize myself for the onslaught of campus life. Each inhale... and exhale... in the shade of Jasper Ridge's bay laurels became my new source of caffeine, keeping me refreshed through the weeks.

At Jasper Ridge I found a true love for learning. While exploring coevolution and the biochemical pathways of photosynthesis from the pages of a textbook was interesting enough, seeing these processes occur in real time brought meaning and excitement to my studies. The culture at Jasper Ridge, cultivated by its incredible staff and associated professors, taught me what it meant to be truly inquisitive and to never stop looking for explanations. Why does this branch tilt at this angle? How did this chunk of rock get pushed up above this other? Each fine detail became fascinating when put in context of the greater picture. I discovered what it meant to be captivated by the unknown.

Jasper Ridge also became a place of sharing. Although I delighted in giving tours to a diverse range of audiences, I never truly considered myself a teacher. After four years as a docent, however, I had the opportunity to work with twenty-three sixth graders from Eastside College Preparatory School. I sought to channel Jasper Ridge's culture of sharing and learning—constantly reminding all that “there is never a wrong answer!” and asking more questions than answering questions. I learned an incredible amount from these astoundingly bright students. When we stepped onto the trails, soft-spoken Karla suddenly bubbled with questions. Squeamish Ashley converted into a scat dissecting master. Restless Jose gasped and stood still, eyes skyward, as a Red-tailed hawk soared overhead. This past year, I also had the privilege of being a teaching assistant for *BIO 105*, and mentoring Stanford undergrads on their independent research projects. It was here that I decided that whatever career I pursued in the future, I would strive to be an educator.



Spring of 2016 marked the 17th year that students from Eastside College Preparatory School have participated in Jasper Ridge's Eastside Field Studies course. Students spent every Wednesday collecting data and monitoring plant growth in five different ecosystems.

Since that first hectic year at Stanford, the ridge has continued to be a place of personal grounding and inspiration. It was in the JRBP community that I added “lifelong learner” and “lifelong educator” to my list of self-descriptors. The Jasper Ridge community has been my constant these past five years at Stanford, and while I may be graduating this year (woohoo!), I look forward to seeing how Jasper Ridge will continue to inspire and shape my future.



BIO/EARTHSYS 105 students surveying for snakes.

ALBERT WANDUI, '17, Physics



I first heard about Jasper Ridge during my junior year at Stanford. This was a season of rediscovering some childhood passions that I hadn't pursued in a while. My grandfather, who was a safari guide in Kenya, loved being out in nature, completely immersed in the incredible beauty of the African savanna. He passed on his love of nature to me as part of my heritage. However, as I left home to go to high school, this love for nature fell aside. When my grandfather passed away, I set myself to steward his love for nature, preserve it and share it with the next generation in my family—in his memory. So when I got the chance to enroll in *BIO/EARTHSYS 105*, the Jasper Ridge Docent Class, I was overjoyed.

The class was challenging and rigorous, but also immensely rewarding. Even though I had little background in ecology, I learned quickly because of the unique combination of in-class instruction and outdoor exploration. Many times, I left the class feeling like there was a fundamental shift in how I saw and understood the natural world. Taking the class gave me a newfound appreciation for nature and how natural history and geology come together to create the richness and diversity that we see at Jasper Ridge.

My research project was amazingly fulfilling. It became a way for me to give back to the Jasper Ridge community and a way for me to contribute to the collective understanding of what life is really like on the ridge. I worked together with David Weber studying the movement of mammals in and out of the preserve. We set up camera traps at multiple locations along the boundaries of the preserve and week after week, we were able to capture beautiful images of bobcats, mountain lions, coyotes, foxes and deer. We observed their habits and behavior through the eyes of our camera lenses. David and I were able to share our photos, data and what we learned about animal movement with the rest of our class and perhaps students in the future will want to continue this study.

As a recent JRB graduate, I am truly glad to call the ridge my home. Looking back on this past year, I can say with certainty that Jasper Ridge marked a unique pivot point in the course of my undergraduate career. The remarkable experiences, skills, and friendships that started as a member of *BIO/EARTHSYS 105* will be valuable to me not only as a member of the Stanford community but throughout the rest of my life.

It usually makes me nervous to ask for favors. If I had any hesitations about scheduling the tours at Jasper Ridge this past season, that would have been the one. But as I became more familiar with my new job, I realized that the only concern I should have had about the Jasper Ridge community was its overwhelming eagerness to help each other out.

People would ask me how my tours had gone, and give me tips on where to find a notable landmark or a particular plant species. Experienced docents would step up to lead with newer docents for the express purpose of teaching them. Even in my most desperate moments, when an otherwise reasonable tour request might become nearly impossible to fulfill, I would receive a handful of last-minute offers from docents willing to lead—and at least a few apologies from docents who wished they could be there!

There was one wildflower tour for which I could not find a docent in time despite the long notice. This was to no fault of the JR community—I just didn't

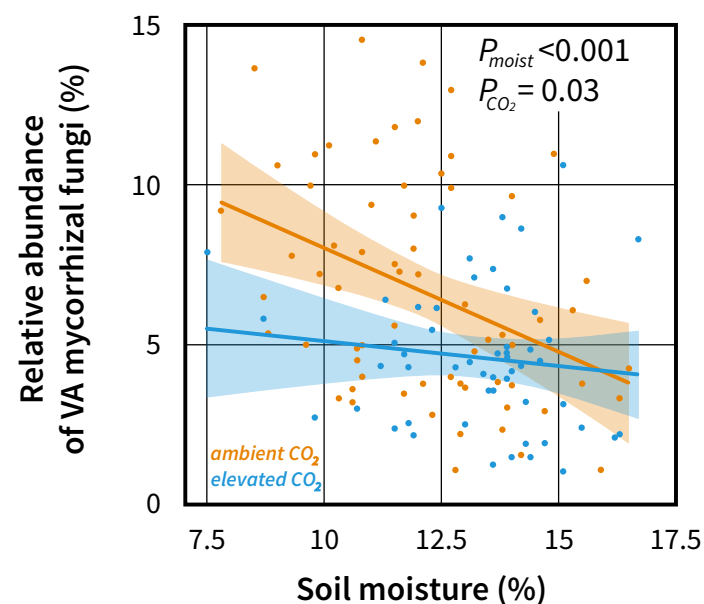


want to bother anyone more than I already had that week. So instead, I cautiously took it on myself, and was surprised by how patient the visitors were despite my limited knowledge of wildflowers. Some of them even pulled up a mobile app for flower identification to help me narrow down the possibilities: "Is it *Triteleia* or Blue dicks?" Whereas scheduling tours helped me to recover my sense of belonging in the Jasper Ridge community, actually leading tours like these reminded me that I could belong as a docent as well.

In hindsight, I should not have been so surprised by my positive experiences. Ever since my initial exposure to the preserve as a member of the 2014 docent class, my interactions with the Jasper Ridge community have only been fruitful and understanding. Nona Chiariello's guest lecture on the Jasper Ridge Global Change Experiment, for example, served as the inspiration for one of my most valuable educational experiences at Stanford. Nona described how combinations of four experimental treatments—CO₂ enrichment, nitrogen fertilization, warming, and increased precipitation—had been acting upon the 136 grassland sections since the experiment's beginning in 1997. The global change treatments, which could go so far as to change the chemistry of the local soil environment, have always been studied for their effects on plant physiology, but nothing similar had been done for soil microbial communities at Jasper Ridge. With a little help from my research advisor Kabir Peay, Nona's lecture became the basis for my spring research project on the effects of global change on soil microbial communities—an endeavor that then led naturally into my honors thesis on the same subject.



Arbuscular mycorrhizal abundance decreases with elevated CO₂



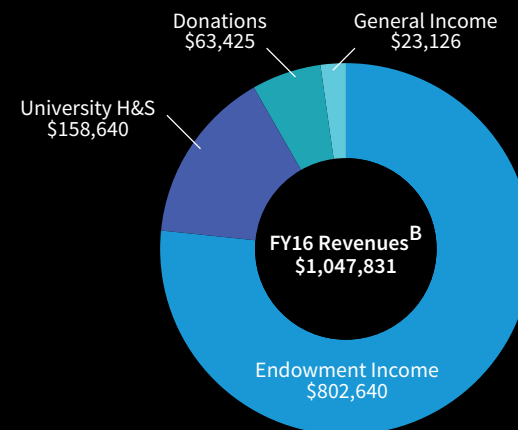
Global change treatments such as elevated carbon dioxide can affect soil microbes directly and also indirectly through their effects on other aspects of the soil environment. This graph illustrates that the abundance of a fungus that forms a symbiosis with plant roots (mycorrhiza) is lowered by elevated CO₂, but this effect can be attributed partly to a CO₂-driven increase in soil moisture (Qin et al, in prep).

THANKS TO THE JRBP COMMUNITY

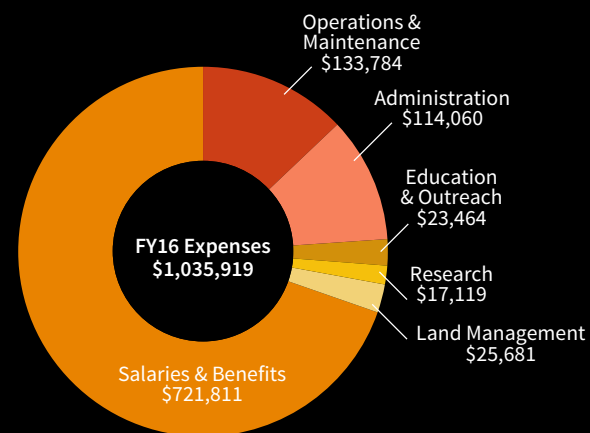
As we close out this year's Annual Report, it is with heartfelt thanks to the entire JRBP community for generosity that comes in many different forms, ranging from simply pitching in when tasks need doing, to conducting faunal and floral surveys, to leading tours, to helping out with education and research projects, to financial support, and much more. These many contributions have been critical for turning Jasper Ridge Biological Preserve into one of the world's premier facilities for discovery and training the next generation of environmental leaders.

Ranger Sverre LeRoy, a PhD student in Earth Systems Science, patrols JRBP.

REVENUES^A



OPERATING EXPENSES^A



^AThese funds include only those that support the infrastructure (staff, facilities, equipment, etc.) required to accomplish our research, education, and preservation missions. Most research projects are externally funded by individual investigators. Additional costs to support educational activities are borne by other campus units.

^BDoes not include the new endowment for The Philippe Cohen Graduate Fellowship.

JASPER RIDGE BIOLOGICAL PRESERVE

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14, 15. TREVOR HÉBERT

16. CINDY WILBER

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18. Bottom: EMILY KIM; **Top:** AMY KIM

19. Portrait: AMY KIM; **Top:** CINDY WILBER

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