Stanford | SCHOOL OF HUMANITIES & SCIENCES

JASPER RIDGE BIOLOGICAL PRESERVE ANNUAL REPORT 2013/14

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On the cover: Red-tailed hawk just after a February sunrise.

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FROM THE FACULTY DIRECTOR

PRESERVE WHAT?

As a biological preserve, JRBP's mission clearly is to preserve something, but the dynamic nature of the world around us can make it hard to figure out exactly what that something should be.

It's not that the Jasper Ridge mission isn't clear. Our focus on research, conservation, and education has served us well, opening doors to fundamental research and inspirational education. Still, the question of what we are trying to preserve is complicated. It's worth reflecting on the alignment between the Jasper Ridge mission and the concept of preservation.

The core problem is that nature is always changing. On the long time scale, we know that the California Current created our Mediterranean-type climate about three thousand years ago, and humans undoubtedly started changing Jasper Ridge soon after. Those changes accelerated with the arrival of Europeans. On a shorter time scale, I first came to Jasper Ridge as a graduate student just as the

recreational "Searsville Park" ended its last summer of operation. Over four decades, there have been truly consequential changes, both positive, such as the rebound in puma numbers, and negative, such as the dramatic decline in the serpentine grassland's spring wildflowers and the invasive spread of yellow star-thistle and French broom. Some changes represent entirely new challenges, such as the arrival of muskrats and wild turkeys. All of this is taking place alongside rapid changes in the climate and the composition of the atmosphere.

So how do we define preservation? I can think of many preservation goals. Each is very different. Each presents advantages and disadvantages. And most are at least partly incompatible with the others. Here are four visions of what to preserve.

PRESERVE INDIVIDUAL SPECIES. Preserving the components of ecosystems could be a means of preserving many other aspects, including ecosystem functions, services, and aesthetics. But this is a challenging objective because many species are present on the preserve only part of the time. When they are off the preserve they are beyond our ability to provide protection. Second, a large fraction of species, including many that may be critical for ecosystem functions, are microscopic and may have never been described. In addition, it's hard to know whether a collection of species really represents an ecosystem. Clearly, a box of watch parts isn't the same as a watch.

PRESERVE ECOSYSTEMS. This might entail identifying each of the major existing types at Jasper Ridge, figuring out which components are essential, and determining what kinds of replacements and reshufflings could be allowed without sacrificing essential features. A problem with this objective is that it is exceedingly difficult to define the key features of an ecosystem and the boundaries at which an ecosystem transitions to something fundamentally different. Observers who focus on appearance, biological diversity, ecosystem function, or resilience would set that boundary in different places.

PRESERVE KEY FUNCTIONS OR SERVICES. For some key functions, it might be feasible to identify ranges of allowable flexibility. For example, different mixes of grassland species might yield comparable primary production, food resources for small mammals, or wildfire risk. But it's very difficult to know whether an ecosystem designed to provide a given set of functions or services would provide others that might be equally important. Could we manage Jasper Ridge at least partly for compelling visitor experiences? Is that possible, if the essence is a perception of wildness?

PRESERVE NATURAL DYNAMICS. If we had a clear picture of the rate of ecosystem change, we might manage Jasper Ridge so that it changes at some kind of "natural" rate. But if we alter the dynamics, might one argue that every study of ecosystem dynamics at Jasper Ridge is simply looking at the consequences of management decisions?

None of the options is clearly "right," and none is clearly feasible. This leaves us in a real-life situation of needing to work with goals that are somewhat ill-defined and with criteria that look different from different perspectives.

How should we guide management without crisp big-picture objectives? My philosophy has four components. The first is to manage with the lightest touch possible, respecting the path that nature determines. Second, we have the opportunity and the responsibility to learn by doing. In our everyday management decisions, we continuously face the question of whether to remove an invasive species, exclude an animal, or mow here rather than there. Docents and staff have managed to keep up with removal of certain invasive plants (e.g., stinkwort, pampas grass, tree-of-heaven), and are making inroads against others (e.g., French broom, yellow star-thistle). We continue to debate an experimental return to cattle grazing as a management tool.

Third, we can learn from others, building on the rich diversity of approaches and outcomes that we see in nearby preserves and parks. Our mission is unique, but wisdom depends on openness to shared knowledge.

Fourth, much of the management of Jasper Ridge is grounded in expert judgment. In some ways, our philosophy may be a bit eclectic, based more on a sense of what is possible than on systematic pursuit of defined goals, but it is based on many decades of collective experience by leading ecologists. The criteria and objectives may not always have the sharpest focus, but they always have a rich "feel" for the system.

I feel much safer with the future of Jasper Ridge in the hands and expert judgment of people who not only care deeply about it but also know that there is no single right definition of "preserve." Our highest mission needs to be assuring that future generations of scientists, conservationists, and students continue to benefit from this unique and complex place.

—CHRIS FIELD, PhD '81

FROM THE EXECUTIVE DIRECTOR

I often find myself explaining to others how biological field stations are at the forefront of understanding our rapidly changing natural world. I am an avid believer that these sites are crucial to addressing some of the most vexing environmental challenges facing society.

This year, two seminal publications by the National Academy of Sciences' National Research Council (NRC) made my job easier. These publications documented how both field stations and marine laboratories are essential parts of the nation's educational and research infrastructure (*Enhancing the Value and Sustainability of Field Stations and Marine Laboratories in the 21st Century*), documenting why they are important, as well as the significant challenges they face in this century (*Convergence: Facilitating Transdisciplinary Integration of Life Science, Physical Science, Engineering, and Beyond*).

The *Convergence* publication was particularly lucid about a unique phenomenon that people associated with field stations have long appreciated — field stations are not hindered by disciplinary constraints (or not restricted to any one discipline). Instead, they are places where interdisciplinary perspectives are encouraged and knowledge from numerous disciplines is more easily integrated. The NRC report refers to this integration as "convergence." I like the term, because it creates the sense of multiple paths or ways of knowing that frame challenges while also illuminating ways to move forward.

The Jasper Ridge community embodies the spirit of convergence, both in how we use the preserve as a point of discovery and as a path for engaging with the greater world. One need only read the recommendations of our 2004 strategic plan (http://jrbp.stanford.edu/stratplan.php) to see just how explicit this convergence thinking is to the preserve's future. But the NRC doesn't write reports of this sort just to express admiration (though that never hurts). It also identified major challenges that field stations face, both individually and as a community, if they (we) are to continue to be viable and valuable contributors.

As I look at those challenges, it is clear that Jasper Ridge has addressed many of these pitfalls, making us ideally positioned to continue our tradition of both broadening and deepening our understanding of many environmental challenges in the coming decades. While the NRC report makes nine specific recommendations, I want to draw attention to four that highlight why I think JR will continue its long tradition of being a major contributor to environmental solutions.

FIRST, biological field stations should identify and support the development of their unique scientific and educational assets that bring together diverse disciplines and promote “convergence.” It is precisely that process that characterizes the preserve. A cursory analysis of the number of schools, departments, and programs that take advantage of the preserve reflects the convergence that the NRC is trying to promote, with many of our projects involving teams of researchers and students from multiple disciplines and institutions. For instance, in the past five years, students and researchers from all seven schools within Stanford University have engaged in research and educational activities at the preserve. During that period, dozens of researchers from over 30 institutions around the country and world have conducted work at the preserve.

THE SECOND recommendation notes that field stations should be instrumental in training the next generation(s) of scientists by deepening interest in the STEM (science, technology, engineering, and mathematics) disciplines through active learning and collaborative research. A review of the research and education sections of this and past annual reports demonstrates how rich and active the program activities at the preserve are at promoting STEM education.

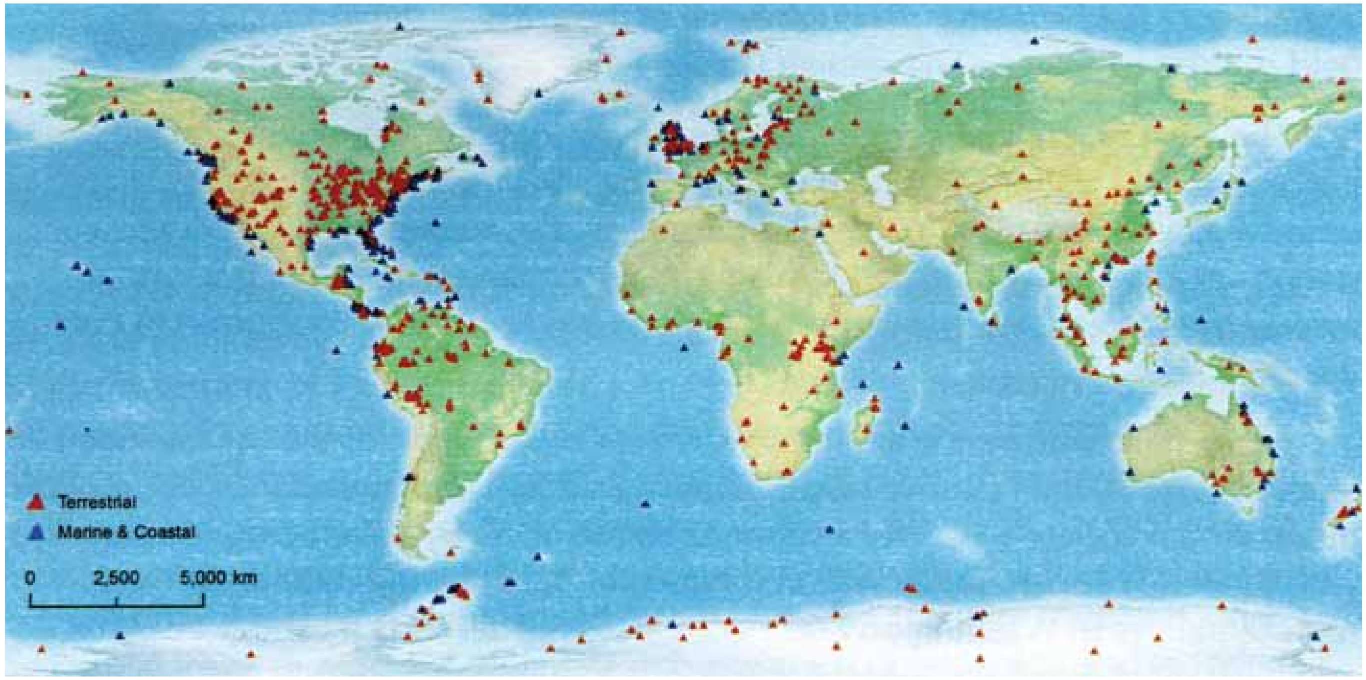
A THIRD recommendation is that field stations should broaden efforts to engage the public in science, especially given the new technologies that are now available. Engaging the public has always been one of the preserve’s great strengths, especially through its docent program. From bat and bird monitoring to ant surveys, to maintenance of the JR herbarium, citizen science is a core part of how the preserve functions. At the same time the NSF-funded installation of our wireless mesh network has positioned Jasper Ridge to start exploring more opportunities for public engagement without necessarily increasing the human footprint. We are now beginning the process of recreating our website and developing a social media presence that

FIGURE 1-1

WORLD MAP OF BIOLOGICAL FIELD STATIONS AND MARINE LABORATORIES. GLOBAL DISTRIBUTION OF 918 TERRESTRIAL, COASTAL, AND MARINE STATIONS ACCORDING TO DATABASES PROVIDED BY THE ROYAL GEOGRAPHICAL SOCIETY, THE NATIONAL ASSOCIATION OF MARINE LABORATORIES, AND THE ORGANIZATION OF BIOLOGICAL FIELD STATIONS; AND INFORMATION GATHERED FROM WEBSITES OF THE ASSOCIATION OF EUROPEAN MARINE BIOLOGICAL LABORATORIES, THE INSTITUTE OF BIOLOGICAL PROBLEMS OF THE NORTH THE JAPANESE ASSOCIATION OF MARINE BIOLOGY, THE INTERNATIONAL NETWORK FOR TERRESTRIAL RESEARCH AND MONITORING OF THE ARCTIC, THE SMITHSONIAN TROPICAL RESEARCH INSTITUTES, THE TROPICAL ECOLOGY ASSESSMENT AND MONITORING NETWORK, THE WORLD ASSOCIATION OF MARINE STATIONS, AND THE GOOGLE SEARCH ENGINE.

—from the NRC report on field stations

To see a short video about the NRC report and its findings, go to http://tinyurl.com/na4g7s2



will have as one of its objectives to further engage the public in the science and natural history of the preserve.

A FOURTH recommendation is that host institutions should develop business plans that "establish reliable base funding commitments that can be supplemented with funding from diverse sources." One of the important trends in the last decade has been an increase in the endowment to support the preserve. More predictable support from the School of Humanities & Sciences, as well as more reliable annual giving, has helped secure the preserve's ability to plan new initiatives, meet future challenges, and explore new opportunities (such as revamping our website in the coming year). From personal and professional experience, I am often appalled at how rarely biological field stations have reliable, predictable budgets that come close to their operating needs. Jasper Ridge is one of those rare examples of field stations with strong institutional support and a committed community that helps assure its future.

Recent events at JR also attest to how we are in keeping with the report's recommendations. For example, by this time next year Stanford University will have identified a preferred option for the future of Searsville Dam and reservoir. The process the University has adopted reflects a convergence approach. As some of you are aware, about two years ago Stanford embarked on a comprehensive effort to assess options for the future of Searsville Dam and the associated reservoir complex. The Searsville Alternatives Study is led by a Steering Committee composed of some of Stanford's most talented environmental faculty as well as senior administrators *(see the list on page 29)*. The faculty and administrators represent disciplinary expertise in the earth sciences, global ecology, hydrology, conservation biology, environmental engineering, environmental law, history, archaeology, risk management, and land-use change.

In addition to Stanford's Steering Committee, there is an advisory group composed of the various interests within the San Francisquito Creek watershed and a Stanford working group composed of Stanford staff providing support to the Steering Committee. These groups demonstrate the degree to which Jasper Ridge is integral to and integrated into a larger landscape (and, hence, a conduit for important discoveries), but also, what it means to manage a field station under dramatically changing circumstances. Field stations must be nimble enough to address legacy impacts and challenging economic times, while being flexible enough to adapt to and integrate changing research technologies within a changing landscape.

Other important events of the past year include the installation of the Stanford Solar Decathlon Start. Home (http://news.stanford.edu/features/2014/starthome/). The SSD house was conceived, developed, designed, and built by a large contingent of Stanford students for the biannual Department of Energy Solar Decathlon competition. In the short term, this house replaces the old ranger residence; in the long term, it is slated to become housing for long-term visiting researchers/scholars. This is part of a larger effort by the School of Humanities & Sciences to bring the preserve's infrastructure into the 21st century. In the coming year, site planning will begin on upgrading the maintenance yard.

Another significant event this year was the transfer of nine acres of university land to the preserve that was formerly part of the old Boething Tree Nursery at the eastern boundary of Jasper Ridge. While nine acres may not sound like a lot, this additional land will eventually provide an improved riparian buffer to San Francisquito Creek, as well as providing land to conduct experiments that may include considerably more intervention and manipulation than is likely to be allowed on the rest of the preserve.

In closing, I want to express my appreciation to the members of the Jasper Ridge Coordinating Committee. This past year has included meetings very dense in content and the committee members *(see page 29)* provided invaluable advice, input, and support. My job is so much easier thanks to their willingness to give time and thought to the many challenges the preserve faces.

As this annual report attests, it has been an exciting and productive year with many interesting challenges and developments on the horizon. I hope you share my optimism and enthusiasm for the future of this unique biological field station. We could not be where we are without your continued engagement and support.

—PHILLIPPE S. COHEN

Clockwise from top left corner: Native harvester ant (Messor andrei), *Sticky monkeyflower* (Mimulus aurantiacus), *Coast redwoods* (Sequoia sempervirens), *Bee fly* (Bombylius sp) *visiting* Leptosiphon parviflorus, *VOC collection from star-thistle* (Centaurea solstitialis), *Installation of GPS antenna, Black-tailed deer* (Odocoileus hemionus) *browsing live oak* (Quercus agrifolia)

RESEARCH

FROM THE STAFF SCIENTIST

Research at Jasper Ridge is as diverse as the landscape and the forces that formed it. Sliced by the San Andreas fault and sculpted by climate, nature, and human enterprise, JRBP has more than a dozen major habitats and an even greater number of research disciplines.

During 2013–14, investigators from nine departments and programs at Stanford, along with visiting researchers from 18 other institutions, carried out 67 studies. The diversity of research topics can be seen in the year's 21 scientific publications, listed on page 27, as well as in the complete roster of studies (http://jrbp.stanford.edu/appendices2014.php).

The scope of research is also reflected in this year's essays by researchers. We begin with a report from Merav Vonshak comparing Argentine ant invasion at JRBP and in more urbanized areas nearby. Although JRBP's small size and developed surroundings increase its invasibility, Merav's work demonstrates a flip side—undisturbed sites at JRBP can be compared with less protected areas in such close proximity that confounding variables like climate are held essentially constant.

The converse—a very invasive species in altered climates—is addressed by Marina Oster based on her work in the Jasper Ridge global change experiment. Such studies are hitting home with growing urgency. In 2014 the atmospheric CO_2 concentration crossed 400 ppm for the first time in over a million years. Just within the span of the global change experiment, it has risen nine percent. Marina describes a remarkable food chain involving yellow star-thistle and its release of chemical "distress calls" under ambient versus elevated CO_2.

The 2013–14 year was one of JRBP's driest on record and brought home the possible drought dimensions of climate change. George Koch reports on the severity of moisture stress in coast redwoods and how they might respond to a climatic shift to more intense drought. For grassland communities, Emily Dittmar explores how drought can erase differences in the typical selective pressures on serpentine and nonserpentine soils that help maintain the beautiful duet of pink- and white-flowered forms of *Leptosiphon*, a treasure chest for studying evolution.

Interacting populations not only enrich the diversity of an ecosystem, they also record its history and shape its future. Oaks are particularly significant, as they define more Jasper Ridge plant communities than any other genus and record a host of human imprints such as wood-cutting and altered food webs. With an eye to the future of oak communities, Rodolfo Dirzo highlights new results on the herbivore pressure and mistletoe burden on oaks. Complex interactions also play out among microbial populations that colonize the nectar of flowers. As Rachel Vannette reports, in the blink of a hummingbird's visit to a flower, a microbial community can be set in motion that may carry lessons on how to initiate recovery pathways for damaged ecosystems.

Our closing essay by Ingrid Johanson also looks to the future by examining the plate tectonic forces of the San Andreas fault system and risk of a major earthquake. She shows that it "takes a village" of monitoring stations, among them one at JRBP, to map deformation across the San Francisco Bay Area and the potential for catastrophic damage from a major earthquake.

These seven essays describe a small fraction of the year's research. New studies included camera-trap analysis of bobcats in contrasting habitats; the suitability of lake sediments for growing plants; behavioral correlates of harvester ant microbiomes; soil fungal diversity and time series analysis in the global change experiment; diversity and behavior of bee pollinators; soil chemistry and carbon storage; acoustical survey of birds; and prehistoric rock-shelters.

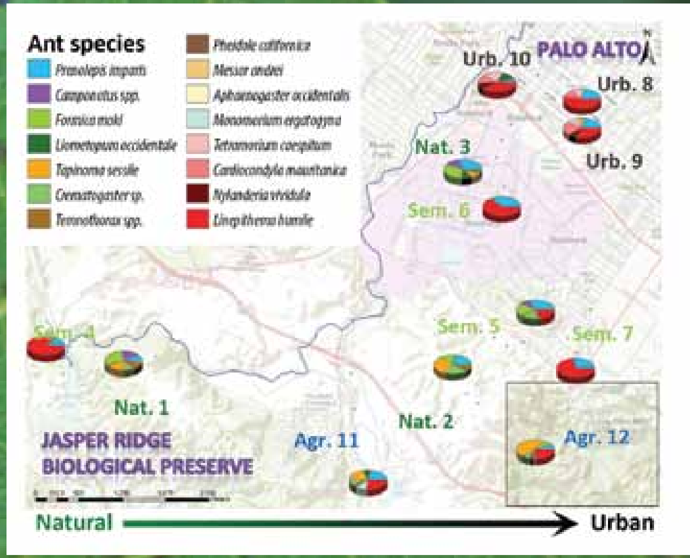
At the other end of the spectrum, 14 studies have been active for at least ten years. The most recent addition to the "long-term" ranks is Bill Graves's study of western leatherwood (*Dirca occidentalis*). Two long-term studies had 20th anniversaries this year, the seismic monitoring station and the Argentine ant survey. Interestingly, both of them demonstrate the power of partnerships—for seismic monitoring, a partnership of UC Berkeley, the US Geological Survey, and Stanford; for the ant survey, a partnership of researchers and volunteers.

Working with investigators who represent many disciplines and institutions, I am always struck by the range of interests they bring to Jasper Ridge. But I am equally struck by the common threads across studies: similarity of impacts from climatic events, parallel uses of technology, the evolution of long term studies and their off shoots, and, most notably, the pursuit of new knowledge to help preserve natural and cultural resources. More than a collection of studies, Jasper Ridge is a crossroads of research on questions of global significance.

—NONA CHIARIELLO

ANT COMMUNITIES ALONG AN URBAN–RURAL GRADIENT

MERAV VONSHAK, Postdoctoral scholar, Dept. of Biology



Urban habitats are going through a faunal and floral homogenization process worldwide. In my research, I am studying how invasive species, originating from urban habitats, affect nearby natural habitats and what the possible management implications might be. I have monitored the species richness and abundance of ants in natural, semi-natural, urban, and agricultural habitats for one year along a rural–urban gradient from Jasper Ridge to Palo Alto. In addition I measured environmental variables that are either human-related or non-related in order to identify which affect ant distribution the most. I also compared the foraging behavior of ants in natural and semi-natural sites.

I found that distance from buildings was the most important environmental variable affecting ant distribution. In a well-protected site in JRBP (Nat.1), I documented nine native ant species, while in a semi-natural site 800 meters away (800 meters east), with a similar habitat but very close to JRBP's buildings, I mostly found two ant species. These were *Linepithema humile* (the Argentine ant) and *Prenolepis imparis* (the winter ant). *L. humile* is a well-known invasive species, spreading in California since 1907 and displacing most of the native species where it has invaded. *P. imparis* is a widespread native species, which frequently, and remarkably, coexists with *L. humile.*

Consistent with my predictions regarding species richness, I found that natural habitats are very rich in native ant species but have no invasive species, whereas urban habitats have high richness of both native and invasive species. Surprisingly, I found the highest ant abundance in the semi-natural habitat, and this was true across all seasons. This trend in abundance was driven mainly by the Argentine ant, which accounted for 81.13% of all individuals that recruited to stations with food bait.

These results led me to test how *L. humile* affects the foraging ability of native species. I've compared ant foraging behavior in two pairs of natural and semi-natural sites, and found that *L. humile* and *P. imparis* affect each other's ability to dominate food baits. Moreover, I've found that *L. humile* scored highest at every parameter of foraging behavior that I measured. Among nine ant species that I compared, *L. humile* discovered baits first, stayed at baits longer, and had the highest score on the "ant-hour" index (number of workers x time spent at baits).

My study has important implications for conservation of semi-natural habitats. Despite many similarities of natural and semi-natural habitats, proximity to buildings in the latter has a detrimental effect on native ant communities and possibly on other organisms.

Photo: Winter ant (Prenolepis imparis) *worker tending* homopterans.

STAR-THISTLE'S CHEMICAL COMMUNICATION APPROACH TO DEFENSE

MARINA OSTER, Doctoral candidate, Dept. of Biology

Jasper Ridge has many textbook examples of plants whose chemicals attract pollinators, deter herbivores, or alter the palatability of their herbivores, and many more instances of chemical communication likely exist. My dissertation focused on an unusual and complex example that links three trophic levels and bears on coevolution, invasion biology, and global change.

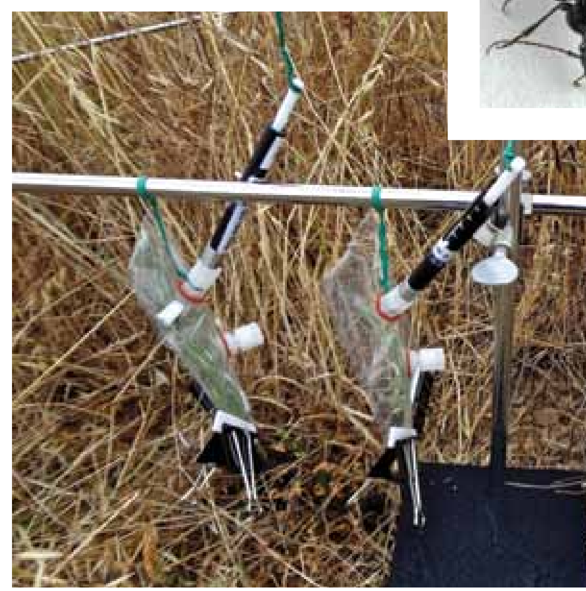
Yellow star-thistle (*Centaurea solstitialis*) is a highly invasive, noxious weed that sickens horses but is readily consumed by the gray garden slug, *Deroceras reticulatum*, itself an exotic species. The slug in turn is food for certain ground beetles, including *Pterostichus melanarius* (yet another exotic) and *Scaphinotus interruptus* (a native). Star-thistle emits chemicals that appear defensive in other plants, and I sought to understand their possible role in the "tri-trophic" interaction of star-thistle, slugs, and ground beetles.

My field studies took place in the Jasper Ridge global change experiment, where previous research found that elevated CO_2 increased star-thistle growth, yet seedlings were very vulnerable to slugs. I planted star-thistle seedlings—protected by copper cages—in warmed and high CO_2 plots as well as ambient. The next summer, I wounded some plants to simulate slug damage and left others undamaged. I collected their volatile chemicals by enclosing each plant in a Teflon bag along with a specially designed wand with an adsorbent fiber, and then analyzed the adsorbed chemicals. I found that wounded plants released a mix of 14 volatile organic compounds (VOCs), and the mix was unaffected by elevated CO_2. Undamaged plants released no detectible VOCs.

I also studied beetle responses to star-thistle's VOCs. I placed a beetle at the base of a Y-shaped glass tube and tracked its movement into the other two arms: one led to a chamber with an intact star-thistle plant, the other to a slug-damaged plant. A continuous air stream passed from each chamber to the beetle, providing chemical directions.

I found that *P. melanarius* beetles preferentially moved toward the damaged plant. This supports the idea that star-thistle defends itself against slug herbivory by releasing volatile chemicals that recruit beetles that prey on the slugs. However, this scenario consists entirely of European species. The native *Scaphinotus* beetle showed no preference in the navigation test.

My research highlights the complexity of biological invasions in a global change context. If rising CO_2 levels facilitate invasion of star-thistle, the resulting interactions might alter the recruitment of non-native slugs, with implications for the abundance of native versus non-native ground beetles. Experiments like mine will help catalog the ways in which ecosystem responses to global change might be amplified or suppressed by networks of chemical communication.



REDWOODS AS SENTINELS OF CHANGE ALONG THE CALIFORNIA COAST

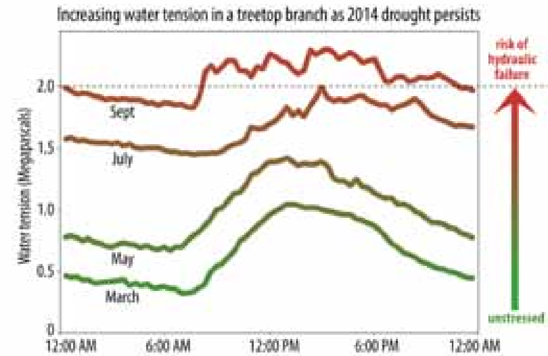
GEORGE KOCH '78, PhD '88, Professor, Northern Arizona University

The small stands of second-growth coast redwoods at Jasper Ridge are a link to the region's history from the logging era to 20th century conservation. The incomparable lumber of coast redwoods gave rise to a multitude of logging operations in the Santa Cruz Mountains, along with towns such as Searsville, but the logging frenzy also spurred action by conservationists and scientists, among them Stanford's first president. My research addresses what redwoods face in the 21st century—a changing climate. In 2013, I added a Jasper Ridge tree to my study of redwoods along their Coast Range distribution from Big Sur to the Oregon border.

I first encountered the Jasper Ridge redwoods as a biology student studying how the world's tallest trees draw water from the soil to their canopy tops. The analogy we learned was that the column of water in a tree is like a rubber band being pulled downward by gravity and upward by evaporation from leaves to the atmosphere. Until recently, studying that mechanism required climbing the tree to cut twigs, and measuring the water tension in each twig using a pressurized steel chamber. The work was slow and sometimes dangerous, and critical measurements had to be made before dawn.

Now it's possible to measure water stress continuously over a period of months with an electronic sensor mounted to a treetop branch. These devices record the daily cycle of greater stress in the afternoon as water uptake from the soil falls behind water loss from the needles, and less stress at night as the tree equilibrates with soil moisture. The key pre-dawn period of minimum stress provides an index of the tree's water supply.

As California's drought worsened in 2014, the Jasper Ridge tree experienced intensifying water stress, even though it is growing on the bank of San Francisquito Creek. Pre-dawn measurements showed a steady decline in soil moisture. As drought persisted, the daily stress cycle dampened slightly, indicating that the tree was opening its leaf pores only partially, conserving some moisture. Still, by midsummer, water stress in late afternoon was near "hydraulic failure," the level of tension at which the column of water breaks and the tree loses some of the plumbing that supplies water to its leaves.



The midsummer moisture stress in the Jasper Ridge tree was similar to that of trees three times taller in wet coastal forests. This illustrates how drought and height compound one another to determine the degree of moisture stress at a redwood's treetop.

The future of redwoods in a warmer, drier climate is uncertain but likely entails a cost in terms of reduced height and slower growth, especially in eastern foothill areas like Jasper Ridge. An icon of California's history of logging and then conservation, these magnificent trees could now serve as sentinels of climate change along the California coast.

ADAPTIVE DIFFERENTIATION AT A SMALL GEOGRAPHIC SCALE

EMILY DITTMAR, Doctoral candidate, Michigan State University

Perhaps you have noticed pink-flowered *Leptosiphon parviflorus* in some areas of the grassland at Jasper Ridge, while in other areas, mostly white-flowered individuals are found. This unique system allows me to investigate the mechanisms that generate and maintain diversity.

The pink flowers at Jasper Ridge are found on serpentine soil, while on sandstone soil, white-flowered plants are more common. When grown on greenhouse soil, these populations retain these flower colors, and plants from the serpentine population flower earlier than plants from the sandstone population. Prior work in our lab has shown that these populations of *L. parviflorus* are mating with each other, but if they are exchanging genes and located in nearby areas, what is maintaining their differences?

To understand whether adaptation to soil type is driving this variation, I grew plants from both populations on both soil types for three years to determine whether the native population performed best in each environment. On serpentine soil, individuals from the sandstone population died before flowering, while serpentine individuals survived to reproduce. On sandstone soils, survival was similar between the populations, but sandstone plants produced a greater number of flowers. Thus, each population is locally adapted to its respective soil type.

I also grew plants that were a genetic mixture of both types and found evidence that in some years, early flowering pink flowers are favored on serpentine soil and white flowers with intermediate flowering times are favored on sandstone soil. Because of the low water-holding capacity of serpentine soils, differences in drought tolerance may play a role in adaptive differentiation among these populations. Early flowering is consistently favored on serpentine soil, likely because it dries up earlier in the season than sandstone soil. However, the relationship between the studied traits and fitness has varied across the three years of my study. The droughts during 2013 and 2014 may have obscured patterns of selection if sandstone soils were drier than average.

The relationship between flower color and soil adaptation is intriguing. Flower color does not seem to affect pollinator visitation and some studies suggest a link between pigmentation and stress tolerance in plants. I am investigating whether the flower color differences I observe may be related to drought tolerance.

This system is providing insight into how adaptation initiates divergence among closely related populations.

OAK TREES: DOMINANT AND VULNERABLE

RODOLFO DIRZO, Professor, Dept. of Biology

One of the most distinguishable features of the physiognomy of Jasper Ridge and, indeed, of the Northern California landscapes, is the majestic oak trees and the oak-dominated communities they form *(see background photograph)*. The oaks' abundance, size, and longevity make them a group of "foundational trees"—highly interactive species that influence numerous processes, including those resulting from biotic interactions with many other organisms.

Another distinguishable aspect of the physiognomy of oak-dominated communities is that the large, mature trees do not seem to be accompanied by abundant juvenile trees, an aspect denoting that oak populations are experiencing limitations in their

regeneration potential. Indeed, for all oak species at Jasper Ridge, frequency-distribution of tree size histograms makes evident the absence or scarcity of individuals in the sapling/juvenile categories *(see Figure 1)*. One of my lab's lines of research is to examine if, and to what extent, deer grazing affects vegetative performance and survival of seedlings and saplings of live, valley, and blue oaks. Using a paired design with 75 replicates of individually caged/uncaged plants *(photo below)*, we have found that not only is performance (stem, branches, and leaf production) significantly impacted by herbivory, but these differences translate into a dramatic difference in survival *(see Figure 2)*: while 91% of caged plants survived, only 66% of uncaged plants were alive five years after the experiment started.

Related work published this year by Aida López-Sánchez and other members of my lab uncovered that this situation is exacerbated in neighboring oak woodlands where cattle grazing (a common land use in the area) is also present.

Another distinctive aspect of the contemporary physiognomy of the Jasper Ridge oak communities is the presence of hemi-parasitic mistletoes. In collaboration with Greg Asner, using high-resolution airborne imaging spectroscopy and Light Detection and Ranging (LiDAR), postdoctoral fellows Jomar Barbosa and Esther Sebastian proved that this technology can be used, with great accuracy, to quantify mistletoe infestation on oaks. This work also showed that the magnitude of infection varies spatially, with the proportion of the host infested increasing from trees within forest patches, to forest edges, to isolated trees *(see Figure 3)*. This survey also serves as a baseline for monitoring the spatio-temporal dynamics of infestation, and possible correlation with environmental variables.

Our research on oak-biotic interactions highlights that these iconic trees are dominant and yet vulnerable species, particularly in light of current and future anthropogenic change.

FIGURE 2. DIFFERENTIAL SURVIVAL OF CAGED AND UNCAGED *QUERCUS AGRIFOLIA*

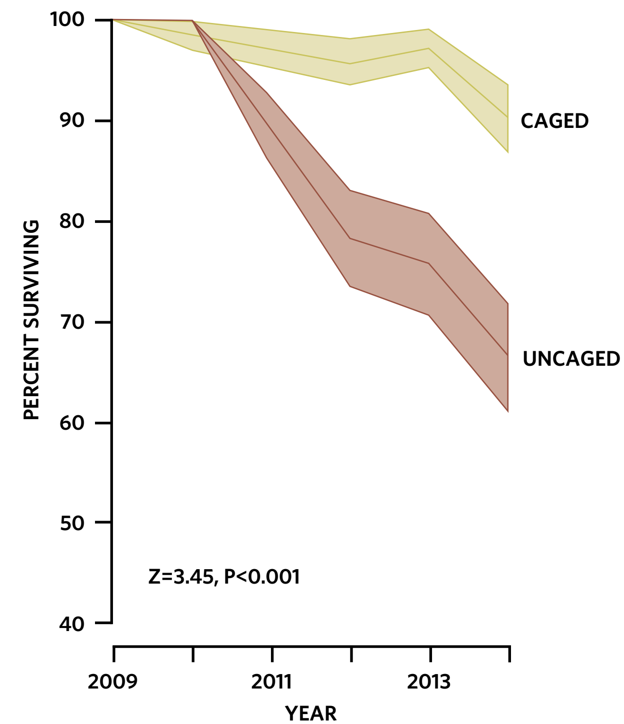


FIGURE 1. SIZE DISTRIBUTION OF BLUE OAKS

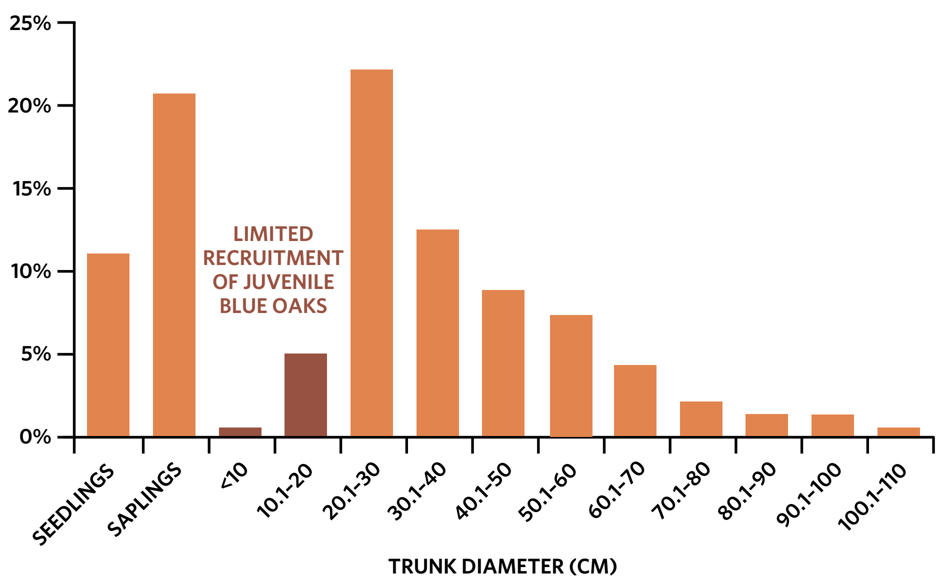
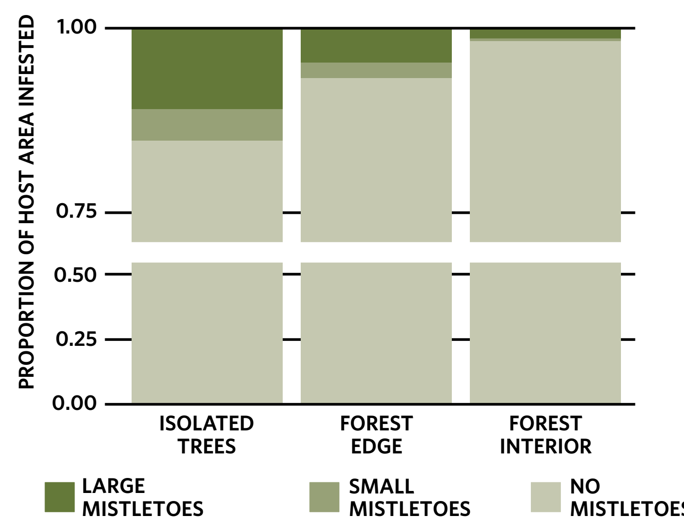


FIGURE 3. MISTLETOE INFESTATION ON OAKS



MICROBES IN THE MONKEYFLOWERS

RACHEL L. VANNETTE, Postdoctoral scholar, Dept. of Biology

Sticky monkeyflower, or *Mimulus aurantiacus*, dots the hills of Jasper Ridge. The cheery orange blooms, replete with nectar and favored as a food source by Anna's hummingbirds, hide a secret: bacteria and yeasts flourish in floral nectar. In collaboration with assistant professor Tadashi Fukami and other members of his lab, my research examines the ecological role of these nectar-dwelling microbes.

Many yeasts and bacteria are characterized by their ability to grow in sugary solutions and renowned for their fermentation products like alcohol and vinegar. If the nectar-dwelling microbes that we study exhibit similar traits to their domesticated relatives, they could have stunning chemical effects on floral nectar. The products of these changes may affect plants or pollinators.

Using a series of field surveys, experiments, and laboratory analyses, we have begun to uncover some answers. With Fukami and Marie Gauthier, we found that yeasts and bacteria differentially affect nectar chemistry. For example, *Gluconobacter*, an acetic acid bacterium, can reduce the concentration of sugars in nectar by 30% and dramatically increase nectar acidity (decreased nectar pH). This may make the nectar less attractive to Anna's hummingbirds: we found that hummingbirds visit bacteria-colonized flowers less. Fewer pollinator visits can result in reduced reproductive success: we have found that flowers inoculated with *Gluconobacter* (but not yeast) produce fewer seeds.

My current work examines how nectar yeasts and bacteria are dispersed among flowers and what factors control their survival in nectar. For example, we mist-net hummingbirds and let them drink sugar water from vials to see what microbes they leave behind in the "pollinated" vial. Like the hummingbird below, the satisfied birds often rest a few moments before flying off.

We have found evidence that both hummingbirds and insect visitors carry microbes to flowers. However, the microbial communities of flowers visited by hummingbirds differ from those that are visited only by smaller insects. In addition, I am also exploring the ways that different plant species or individuals may be able to prevent microbial growth and degradation of nectar.

Female Anna's hummingbird (Calypte anna)

THE BARD NETWORK: SEISMIC MONITORING USING GPS

INGRID JOHANSON, Research seismologist and BARD network manager

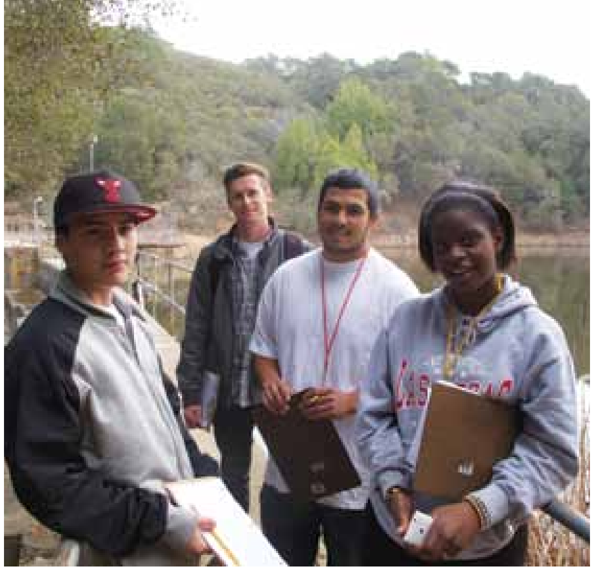
The open horizon of the grassland along Jasper Ridge is providing excellent reception for JRSC, a radome-topped continuous GPS station that is part of the Bay Area Regional Deformation (BARD) network. BARD includes 32 permanently installed and continuously recording GPS sites operated by the UC Berkeley Seismological Lab in cooperation with the US Geological Survey. The BARD network is designed to study how the earth's crust deforms in response to plate tectonics, earthquakes and other types of fault motion for the purpose of seismic hazard assessment and to monitor seismogenic faults for emergency response management.

The San Francisco Bay Area is a geologically complex, tectonically active region that has experienced several historic earthquakes, including the 1989 Loma Prieta earthquake. The San Andreas fault system includes the San Andreas, Hayward, and Calaveras faults, which delineate the boundary between the North American and Pacific tectonic plates. The total rate of relative motion between the North American and Pacific plates is about 50 mm/yr and is distributed across the San Andreas fault system, as well as elsewhere in California and Nevada. If tectonic plates moved past each other smoothly, stations on each side of the boundary would show uniform motion. However, the faults move only sporadically in the form of earthquakes and otherwise are "stuck." This causes the earth's crust to warp around the fault, stretching the crust like a rubber band and putting stress on the fault.

GPS is used to monitor the movement of the crust and determine the size and pattern of deformation and stress in the warped zone, which constrain computer models of fault motion and help determine how big a future earthquake might be. When the stress is too much to withstand and the fault slides suddenly in an earthquake, the pattern of warping that was produced between earthquakes is reversed, and measuring the deformation due to the earthquake will tell us how much and how far the fault slipped.

The figure at left maps this warping. The arrows show the magnitude and direction of station movement relative to one particular station (LUTZ). By comparing the arrows for JRSC (on the North American Plate) and FARB (the Farallon Islands, on the Pacific Plate), we see that relative to JRSC, FARB has moved about 11 mm to the northwest per year, which is less than the total rate of motion between the plates. Even the small difference in motion between JRSC and its nearest station, SLAC, is an indication of warping due to the buildup of stress on the fault and is exactly what we want to resolve in order to figure out how deep the seismogenic portion of the fault goes.


EDUCATION



When people ask me what I love about my job the answer always comes back to the people that I am privileged to work with at the preserve—from our Stanford students (frosh to graduate) and our talented and diverse volunteers, to our K-12 students as highlighted by Eastside Field Studies and the Redwood Environmental Academy of Leadership (REAL). The cumulative and far-reaching effect of the JRBP education program is inspiring and I am thrilled to be able to share real stories of how our program contributes to doing, learning, and teaching ecology and environmental science both at Stanford and the greater community. For this 2013–14 report, Makulumy Alexander-Hills '16, Christina Feng '12, Michael Martin Peñuelas '15, and Phil Leighton '65, have written for us about their work at Jasper Ridge.

—CINDY WILBER, EDUCATION COORDINATOR

Photos at left, top: Redwood Environmental Academy of Leadership (REAL) students with their teacher, Chris Beetley-Hagler during their winter field trip to the preserve; center and bottom: Bio 105 students learning to survey terrestrial invertebrates. Photo, above: Laura Jones MA '85, PhD '91 and students from the Archaeological Field Survey Methods Class. This class has two major components: learning how to find archaeological sites and then how to record those sites to insure their long term preservation. In Spring 2014 the class recorded two circa 1920s Searsville Lake Park dump sites, the Searsville Lake Park bathhouse and beach sites on the east shore of the lake, and re-recorded the Rattlesnake Rocks formation with a special focus on rock shelters.

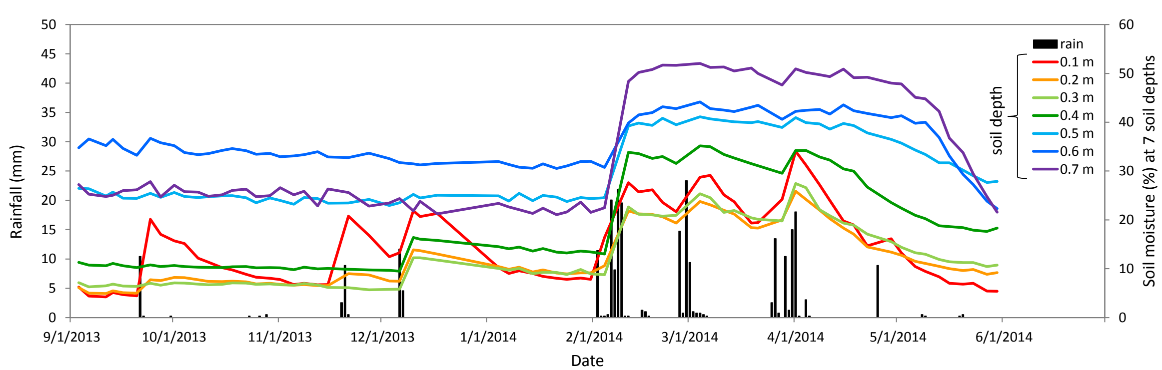
Walking the miles of trails at JR, and learning ecology in the field with Bio 105 as opposed to from a textbook, ultimately shaped the way I view the natural world as a college student—tangible and accessible, not altogether removed from the busy lives of Stanford undergraduates.

It has been my pleasure, in the year or so since I graduated as an official docent of Jasper Ridge, to remain a part of the JR community in a variety of ways. Leading tours allows me to impart knowledge to a variety of visitors, from Stanford Online High School students to local community members who wish to learn more about their own natural environment.

My own field of specialty is in JR plants, and my tours often include pauses to describe the California bay (*Umbellularia californica*) and its role in the spread of sudden oak death or to point out the distinctive bark of the Pacific madrone (*Arbutus menziesii*).

I have also been involved in a year-long research effort as part of the Jasper Ridge Global Change Experiment (JRGCE), under the mentorship of Chris Field of the Carnegie Institution for Science and Jasper Ridge Faculty Director. I spent last summer establishing a pilot project for a new high-capacitance technology designed to measure soil moisture at various depths within the soil profile. Towards the end of this past spring, we established the fully fledged system in three of the eight blocks at the JRGCE, and I assisted in ensuring the calibration and installation matched the pilot project. The soil moisture system data will allow researchers at the JRGCE to precisely monitor fluctuations in moisture between the various global change 'treatments,' hopefully increasing our understanding of various anticipated climate change effects on the presence of water throughout the soil profile. This may also inform plant species presence under certain treatments, based on water availability at various root depths. The pilot project data set, though limited in size, may allow for an initial investigation of the presence of perennial grasses and forbs in the JRGCE; this analysis will serve as the final paper for my Earth Systems internship.

Jasper Ridge has allowed me to expand my academic explorations beyond the classroom and participate in science, education, and immeasurable amounts of fun. The preserve and community will always be a home away from home for me.



CHRISTINA FENG '12

Every time the Main Gate slowly swings open, I know that I'm in for a new adventure at the ridge. Whether it's the sight of a gopher snake ribboning across the road or a flock of quail nervously peering out from the coyote brush, there is always some event that reawakens me to how different this place is from any other part of campus.

Over the years and the innumerable bike rides, my avenues for growth through Jasper Ridge have evolved. Through the docent course, I graduated from being completely clueless about Californian systems (I'm from West Virginia) and unpracticed in field ecology to having a firm foundation for further learning in both areas. Not only can I now explore the surrounding Bay Area and recognize biota that I learned at JR, but I can also go to entirely different localities and still observe common ecological themes and familiar taxonomic characteristics. Looking back, I am amazed at just how many opportunities and life experiences stemmed from those few months of class and how many doors they have opened for me.

The summer after my sophomore year, I conducted summer research at the Jasper Ridge Global Change Experiment (JRGCE) examining how various factors (singly and in combination) affected the prospect of native grassland restoration. Under Nona Chiariello's expert guidance, a fellow intern and I assiduously surveyed new seedlings in every plot and quadrat, processed plant and soil samples relating to the JRGCE, managed and processed our data, and produced technical papers on our work. Being able to learn the step-by-step process of scientific inquiry was hugely impactful on shaping me to think and act like a field biologist. I also came to hold plant ecology in high regard, and the field courses and research I did down the line in Hawai'i and the Colorado Rockies revolved around the study of plant systems.

After graduation, I have been fortunate enough to prolong my exposure to JR through a job with the Stanford Conservation Program. Not only have I trekked through the more infrequently seen lotic environment flowing through the preserve, but I have been able to actively engage in the education programs that I never could as an undergraduate. It has been surprisingly gratifying for me to have introduced students of all ages to an interest in (if not at least a tolerance for) snakes, fish, and other lesser-loved critters. I now even get to help teach the creek class for Bio 105 and having been a student "creek monkey" while in the same class, it feels that I have really come full circle.

In the end, these experiences at Jasper Ridge have reinforced why the preserve is such an important place to so many people, myself included, in terms of personal and intellectual development. Soon, I will be relocating to the Midwest, but I will forever be grateful for being included in the Jasper Ridge community and glad that it will persist as an institution for experiential learning.

MICHAEL MARTIN PEÑUELAS '15

I decided in middle school that I'd spend my life as a medical doctor. In high school I studied bioethics and the coupling between disease and social responsibility. The summer before college I read public health texts by Stanford faculty to prepare myself. I was on track.

However, one particular spring afternoon in my freshman year, I found myself instead walking a different path. Specifically, I found myself at Jasper Ridge, trailed by a group of extraordinary middle school students.

Months earlier I had signed up for Bio 105. I was tired of the barrage of identically structured intro courses the pre-medical student in college must sweat his or her way through. In Bio 105, I had been afforded the privilege of working with the Eastside Field Studies Program, whereby sixth-graders arrive weekly to JRBP for small-group education in ecology.

That afternoon was a powerfully hot one, and before long I found myself on my knees in a patch of dusty shade. Enjoying the transitory respite, I was practicing what I preached to the students: that to best interact with a subject in nature one should on occasion try to put oneself on the subject's level. The 11-year-olds, at my urging, were currently enthralled by a pitfall trap we had set the day before, one that had in the interim captured something of an entomologist's dream.

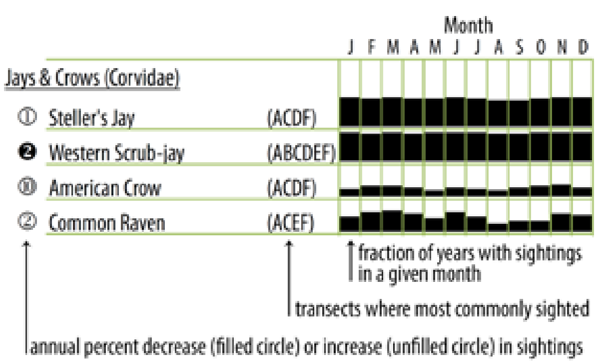
I took a moment while they observed to stretch my neck, turning my eyes towards the sky. There, my still-untrained eyes were by some miracle able to pick out the diagnostic features of a turkey vulture, *Cathartes aura*. It carried something leg-shaped in its beak.

For me, this neck-stretch-vulture-sighting was the moment it all clicked. I realized then that the decaying mammal leg in that vulture's beak was illustrating exactly the mechanism by which my loves of public health and biodiversity could be wed. Today, I'm working in Stanford's Center for Conservation Biology exploring how ties between public health and the services our ecosystems provide for us can be defined. I've started, per my "moment" at JRBP, with vultures and the sanitation services they provide by cleaning up carrion (potential disease reservoirs) in rural landscapes.

But from that day forward, because of the meaning that moment kneeling in the dust had for me, I promised myself that I would keep teaching. I want to do everything in my power to help students like and unlike me have their own moments when things click. Three years on, I teach a new batch of Eastside students each spring and on Fridays I teach high school students through the Redwood Environmental Academy of Leadership (REAL).

I've been lucky enough to see a few of them have "moments." I'd like to think I played a role in some

of those. But I've also recognized something even more important during my teaching. Never once has the backdrop for one of these moments been a traditionally defined, four-walled classroom. I share no ill will towards the classroom. But my anecdotal data really does speak for itself: the inspiration a student can find at Jasper Ridge is something else entirely. A four-walled, roofed-in classroom just doesn't cut it.



JASPER RIDGE BIRDING DATA PROJECT

PHILIP LEIGHTON '65

Between data collected by Bill and Jean Clark and data generated by the transect counts at the preserve, Jasper Ridge has regularly collected bird census data going back to 1979.

However, until the recent birding data project, the information was only available in multiple files, and while most of it had been digitized, much of the data record lacked the format of the current transect database at Jasper Ridge.

Thus it was impossible to pull together a picture of the bird populations from one dataset. The birding census update converted all of the older records to match the format of the current database so that all of the Clark et al. and transect data may now be seen in one place.

The early years of data gathering led to the first Jasper Ridge bird checklist created by the Clarks in 1981 that was revised in 1986. Since then, the newly gathered data havw added 16 species to the checklist, and, of course, the checklist generated using today's expanded database has been revised to reflect numerous changes in common names as well as changes in taxonomic order. The new checklist identifies 194 species that have been seen at Jasper Ridge from 1979 through 2012 while the 1986 checklist had 143 species in the graphic list and an additional list of 35 species for a total of 178 species identified.

While the checklist is based upon 33 actual years of data, the transects as a discrete count area were created in 1989, and it is the data generated since 1989, or 23 years of transect data, that was used for trend analysis. Some challenges included many months missing from the data record along with many months with more than one counting which made the trend analysis potentially shaped by more active periods of record-keeping. Because of this, a standardized set of data was created such that there is one record set per month per transect.

The standardized set was created by averaging either the multiple sets within a given month, or where the data was missing, by averaging the same month from previous and succeeding years. The resulting standardized set of data has been used to create trend analysis for over 130 species; the information from this analysis has been incorporated in the checklist so that a decreasing or increasing trend can be easily seen along with an indication of the strength of that trend. The checklist also indicates, by the thickness of a bar, the frequency by month that a particular species has been seen at Jasper Ridge. For those species for which trend analysis was done, sightings of 37 species have increased over time, and 85 have decreased, some dramatically, out of a total of 134 species analyzed for trends. The western scrub-jay (left) is among the species for which sightings have declined.

BIOACOUSTICS

TREVOR HEBERT

Animal bioacoustics is the study of sound as it relates to animal anatomy, communication and behavior. It also includes the effects of human-generated noise on animals.

Bioacoustics uses recorded animal sounds to analyze signal characteristics such as frequency, duration, and intensity. Computer software can be used for automated processing and classification of animal sounds in order to study animal communication, behavior, hearing, and sound production mechanisms, as well as to identify individual species by the characteristics of the sounds they produce.

Sound can be used to non-invasively monitor wildlife that would otherwise be difficult to observe, such as bats, frogs, insects, or migrating birds. Special microphones allow recording of sounds both above (ultrasonic) and below (infrasonic) the range of human hearing.

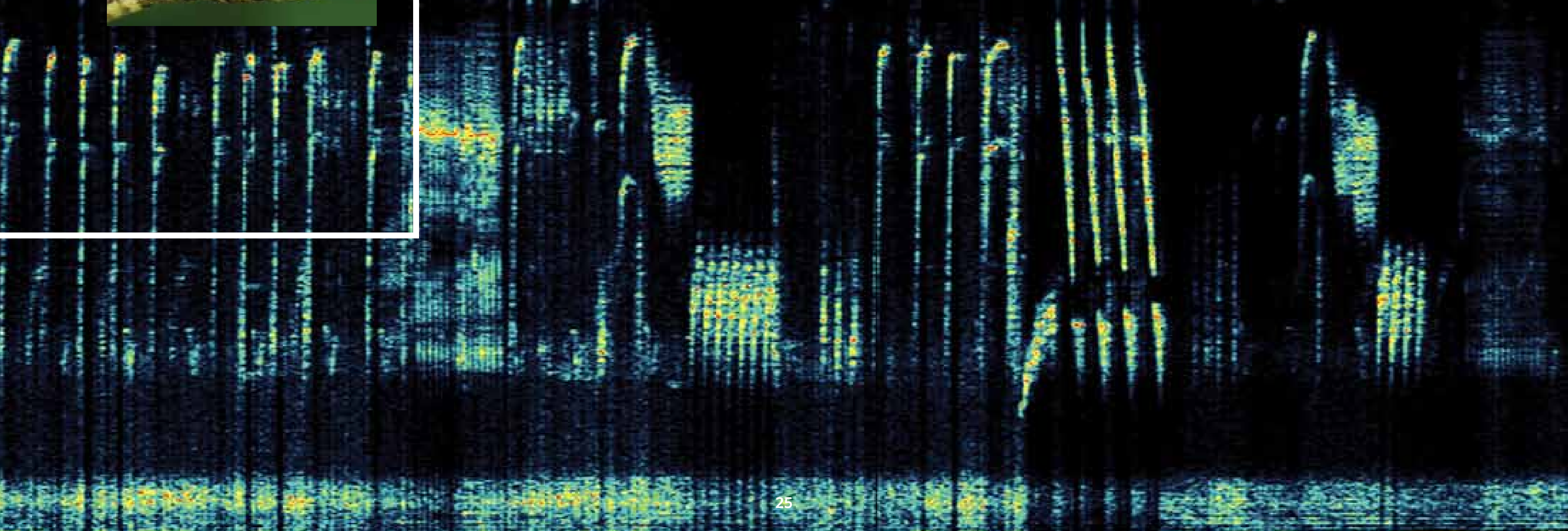
At Jasper Ridge we are using bioacoustics in support of research, monitoring, and technology development and testing. A remote outdoor microphone streaming live audio from an off-trail lakeside location (http://jrbp.stanford.edu/audiostream.php) has been in operation since 2012 and has allowed both the Jasper Ridge community and interested listeners all over the world to hear and appreciate the rich diversity of bird, insect, and amphibian sounds at the preserve as they change with time of day and the seasons. Used in conjunction with the Jasper Ridge bird list, the live audio stream has become a useful tool to help birders learn to identify birds by sound alone. Last fall a female mountain lion vocalization, or "caterwaul," was heard and manually recorded from the live audio stream, the first acoustic documentation of a mountain lion at Jasper Ridge.

Birder and long-time bird recording enthusiast Ron Arps and I are continuing experiments with a sophisticated high-fidelity microphone to enhance the resolution and clarity of the recordings. One of our long term goals would be to use this technology for remote, automated recording and identification of birds and other wildlife that could not otherwise be observed due to the time of day or elusive nature of the species. An archival-quality collection of birdsong recordings from specific locations at the preserve could be used for long-term studies of bird populations at Jasper Ridge including research relating to seasonal or climate change studies.

Computer-generated spectrograms provide a visual, quantitative representation of audio signals and are used for analysis and classification of animal sounds. Real-time spectrogram images in conjunction with the audio stream is another possibility under discussion to help people learn bird songs by allowing them to simultaneously see a visual representation of the bird they are listening to. It may also be possible to monitor for noise pollution impacts on the preserve going forward using baseline ambient noise recordings for various areas of the preserve. Knowledge gained from the other projects here will help inform us as to potential human-generated noise impacts on specific species.

Student Sophie Christel, ’15, for her honors thesis research in Spring 2014, used a Wildlife Acoustics SM2+ field recorder to record bird songs in conjunction with her direct observations of birds in various habitats at Jasper Ridge. Jasper Ridge birder Ron Arps assisted Sophie with initial testing and configuration of the SM2+ recorder. The acoustic bat monitoring program, headed by docent Tom Malloy, has expanded its software toolbox to include Wildlife Acoustics Kaleidoscope analysis software that has allowed the processing of archived bat echolocation recordings from researcher Tom Mudd’s project in 2004-2008 that were saved in the Anabat zero-crossing format. Also, a Stanford biology PhD student, and an electrical engineering undergraduate have applied for researcher permits to conduct bat-related studies at Jasper Ridge which will include analysis of bat echolocation calls from our four acoustic bat monitoring stations (see page 28 in the 2012–2013 Annual Report).

Bioacoustics technology is opening up many new ways to non-invasively monitor animal populations at the preserve and to collect and analyze data for research, education, and management purposes.



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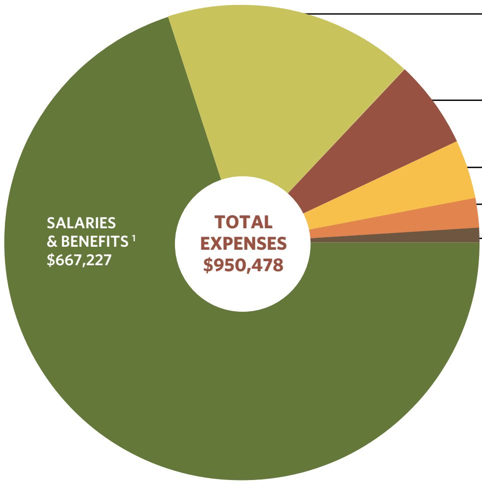
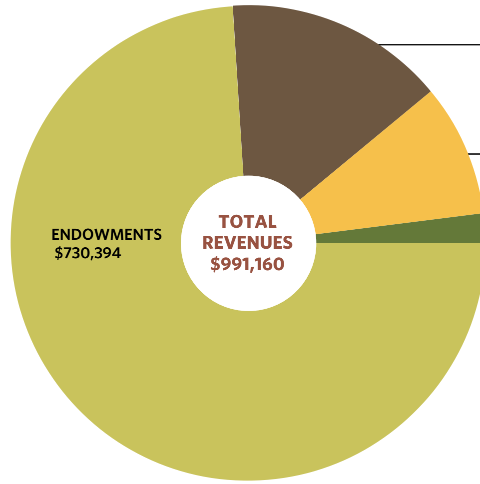
FINANCIAL SUMMARY

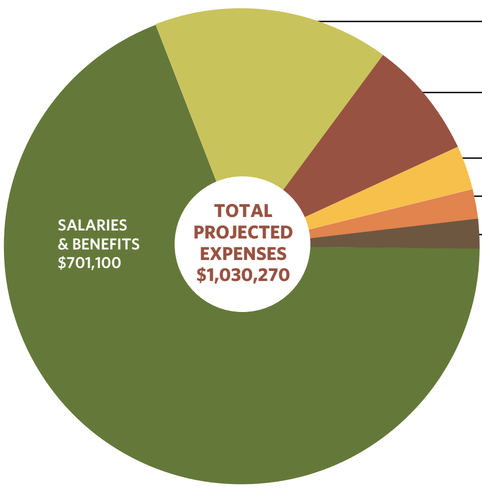
FY14 Expenses



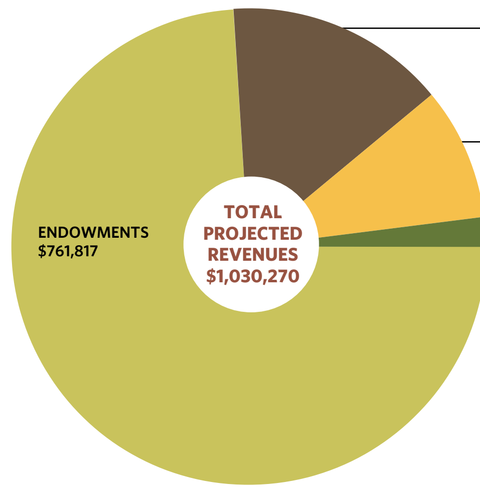
FY14 Revenues



FY15 Projected Expenses



FY15 Projected Revenues



1) Includes $16,291 previously unfunded vacation encumbrance that preceded change in Stanford accounting practices.
2) Includes purchase of new minivan and electric utility vehicle.
3) Includes $2,800 SSD event expenses from previous fiscal year.
4) Includes 50% of web redesign contract expenses.
5) Amount calculated based upon funds needed to meet projected expenses for the coming year.

IN MEMORIAM

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APPENDICES

Summary of Research Activity;
Educational Use
http://jrbp.stanford.edu/appendices2014.php

PHOTOGRAPHY

Cover: Philippe Cohen
Inside front cover; page 1: Philippe Cohen
Page 2: Nona Chiariello
Page 4: Philippe Cohen
Page 7: Linda Cicero, Stanford News Service
Page 8, clockwise from top left: Merav Vonshak, Nona Chiariello, Nona Chiariello, Emily Dittmar, Kara Yeung, Ingrid Johanson, Dan Quinn
Page 10: Merav Vonshak
Page 11: top & middle: Nona Chiariello; bottom: Kara Yeung
Page 12: left: Nona Chiariello; inset: Chris Field
Page 13 (both): Nona Chiariello
Page 14: background photo: Dan Quinn; inset photo: Roger Guevara
Page 16 (both): Nona Chiariello
Page 17: Nona Chiariello
Page 18: Cindy Wilber
Page 19 (all): Cindy Wilber
Page 20: Nona Chiariello
Page 21: Alan Launer
Page 22 (both): Cindy Wilber
Page 23: Dan Quinn
Page 24/25: Caroline Lambert
Page 26: Jack Owicki
Page 29: Dan Quinn
Back cover, clockwise from top left: Dan Quinn, Philippe Cohen, Philippe Cohen, Philippe Cohen, Dan Quinn

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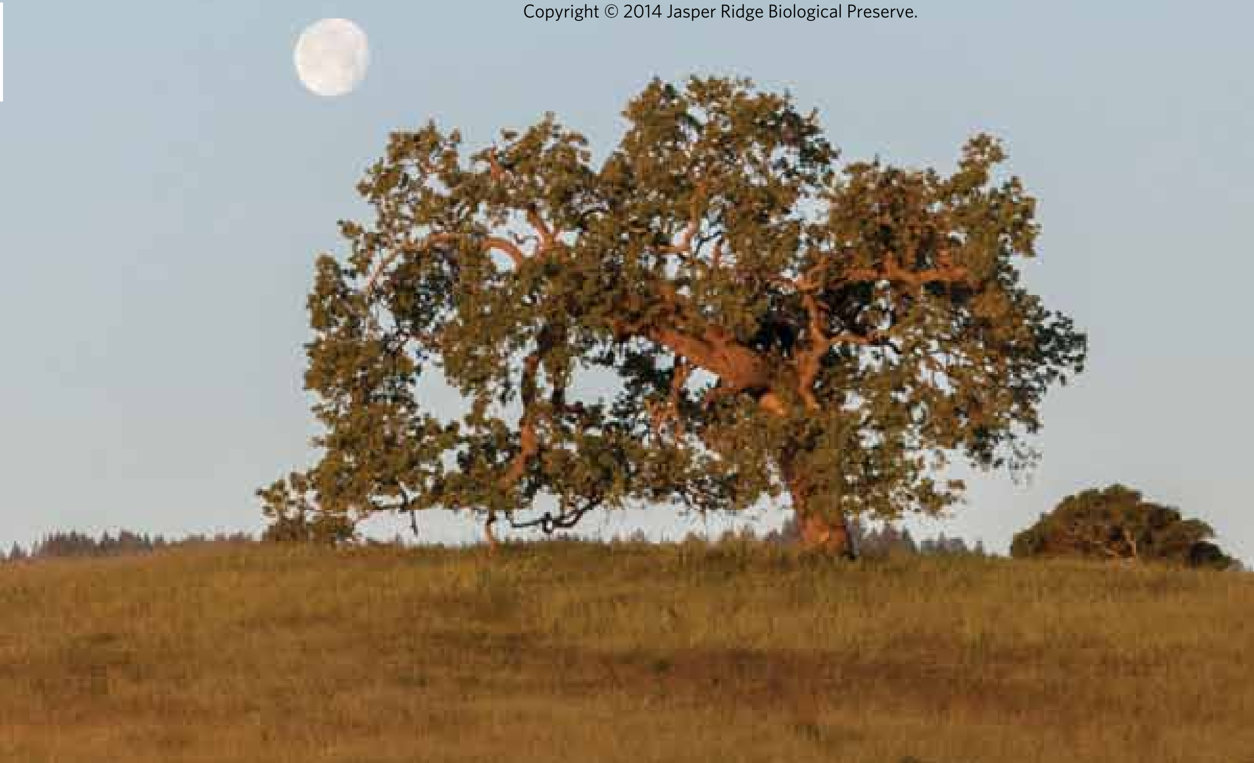



JASPER RIDGE BIOLOGICAL PRESERVE

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