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A few words from the Director of the NRS

This *Transect* describes NRS-based research that aims at unraveling the complexities of the microbial world, explores the far-reaching outreach program at the Stunt Ranch Santa Monica Mountains Reserve, and concludes with a memorable log of the experiences and impressions that thirteen students and two instructors from Gustavus Adolphus College, Minnesota, gained during a one-month intensive field course that uses six NRS reserves. Only the first of these topics requires an introduction.

When researchers examine samples of soil or lake-bottom sediment with a scanning electron microscope, or by epifluorescence microscopy after staining with a DNA-binding fluorescent dye, they see millions of microbial cells

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Mining for microbes at Sedgwick Reserve: Ph.D. student Noah Fierer makes his way through the well-reinforced trench interior of an underground microbial observatory. Photo by Valerie McKenzie

Microbial observatories reveal lively little-known worlds beneath the surfaces of land and lake

Of the estimated 13 to 14 million species on our planet, only about 1.75 million have been scientifically described. The vast majority of undescribed species are microorganisms. A single gram of soil can be home to thousands of kinds of these creatures — both prokaryotic (whose cells lack a true nucleus) and eukaryotic (whose cells have a nucleus) — and we have very little idea of what they're doing or how they coexist. Yet these species are key to understanding life on earth, since, throughout most of the planet's history, they were life on earth.

Recognizing that furthering our knowledge of ecological systems “can only be achieved through a better understanding of microbial abundance, distribution,

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dynamics, community, and how these communities function and are controlled,” the National Science Foundation (NSF) established a Microbial Observatory Program to support environmental microbiology. Research is currently being done at more than thirty sites, including oak woodlands, tropical forests, and salt water estuaries, as well as some of earth’s most extreme environments: alkaline hot springs in Yellowstone National Park, glaciers and tundra in the arctic, hydrothermal vents in the deep ocean, hot pitch lakes in Trinidad, ultradeep caves in South Africa, and polluted underground aquifers at Vandenberg Air Force Base in California. That microorganisms can be found throughout this wide range of extreme environments is a testament to their ability to adapt and survive.

The NRS supports two very different microbial observatories. At the Sedgwick Reserve in Santa Barbara County, scientists Josh Schimel, Trish Holden, and their colleagues are investigating the role of microbes in the soils of oak woodlands. Meanwhile, the Sierra Nevada Aquatic Research Laboratory (SNARL) in the eastern Sierra Nevada serves as a base of operations for a diverse group of researchers studying microbial diversity in hypersaline Mono Lake. Both NRS sites are administered by UC Santa Barbara.

Schimel, whose doctorate is in soil microbiology, appreciates the new focus:

The program is a recognition that microbes are important. You can run an earth system without plants and without animals. But you can't do that without microbes. In fact, throughout much of earth's history, that's the way it was. It was photosynthetic bacteria and decomposing bacteria, and the earth functioned. Plants and animals are really quite recent innovations. So it's critical to understand the role of microorganisms — bacteria, fungi, and other microbes — in the functioning of the biosphere. The greatest biomass on earth is microorganisms — bacteria and single-celled algae in the ocean. There's huge diversity, huge numbers, and huge ecological import. And we really don't understand them very well.

Technology's impact

New molecular techniques, originally developed for biomedical work, have resulted in dramatic breakthroughs for environmental microbiology. Until recently, scientists could not study microorganisms in their natural environment. The only way to identify them was to take them into a laboratory and attempt to grow them. “We could culture probably less than 1 percent of the microorganisms that exist in nature,” Schimel says. “Most of them were very difficult to grow. We knew they were there and we knew they were doing something, but we really didn't know what they did, or what regulated their lives, or how they interacted with other components at an organismal level. At a soil level, we've understood for a hundred years that they decompose organic matter, but we still don't know much about which organisms are active and under what conditions they're active.”

Molecular tools now make it possible to study microorganisms without having to culture them. As Schimel explains, “You can actually extract the DNA and say, ‘Oh, *Bacillus thuringiensis* strain X273 is there.’ Or we might get a sequence of DNA from an organism, and we haven't a clue what it is, but we know it's there. So that allows us to start looking at environmental microorganisms in a different way and get away from the need to grow them in liquid culture in order to study what they do.” — JB



(top) The NRS's Sedgwick Reserve, near Santa Barbara, and (bottom) Mono Lake, with an operations base at the NRS's Sierra Nevada Aquatic Research Laboratory near Mammoth lakes. Photos by Mark Reynolds (top) and Dan Dawson (bottom)

Sedgwick Reserve — the Underground underground

From a distance, the *pedotron* — a word Josh Schimel invented that literally means “soil instrument” — doesn’t look like much. Hidden in the middle of a field full of high grass at the Sedgwick Reserve, the pedotron begins with a fiberglass structure that stands only a few feet above ground. But pull back the fiberglass cover and you will find you are looking into a very deep trench. Descend a few stairs into the trench. Then don a hard hat, flip a light switch on the wall, go down the rest of the scaffolding — and you will realize that the trench is 4 to 5 meters deep, with three levels of scaffolding, and that its walls are heavily instrumented.

“We call ourselves the ‘Underground underground,’” Schimel says with a smile, referring to the small group of soil scientists scattered across various UCSB departments. “Most people regard anything below the first few centimeters of soil as *terra incognita*, the unknown. Our perspective is just the opposite. We wanted to really understand life in the deep soils, and that requires more than drilling a few cores. We needed a facility that would allow regular access and constant monitoring.”

The team has dug two pedotrons, one in the deeper soils of the valley floor and another in the thinner soils of the ridge just above it. Their goal was to compare the microbial populations at the two sites. Both facilities are equipped with instruments designed to capture information on the physical environment at different levels in the soil profile — temperature monitors, moisture gauges, soil gas probes, and soil solution samplers. “We were hop-



Holesome research at Sedgwick Reserve: Allen Doyle, a research specialist who works with Josh Schimel, orchestrated construction of the “pedotron.” Photo by Lynne Dee Althouse

ing to be able to do *in situ* experiments,” Schimel says, “taking intact soil cores from one level and inserting them into another. But that has proven difficult because the soil is so gravelly.”

The pedotrons represent a shift in soil research. Schimel explains:

Most recent work on soil communities and soil microbes only goes about 10 centimeters deep, because that’s where the microbes are most concentrated, that’s where the organic matter is, that’s where the substrate is. So people look at those zones, because they’re interesting. But soils aren’t 10 centimeters deep; they can be tens of meters deep. A soil scientist knows you can’t characterize a soil profile unless you dig a trench at least 1.6 meters deep. The pedotrons give us access 4 to 5 meters down and provide a very different picture.

Admittedly, the highest concentration of microbes may be in the top 10 to 20 centimeters, but the remainder of the soil profile contains much more

mass. So even if microbes are dilute in deep soils, there are still a lot of them. “Big and slow can sometimes outweigh small and fast,” Schimel observes. “In the surface soils, microbes are very active, very rapid, but they’re just a small pool of material when you look at the whole soil profile.”

The pedotrons enable the scientists to address some basic, classic ecological questions that had never been asked about microbes. “Trish Holden [fellow UCSB professor Patricia Holden] and I wanted to tie environmental microbial ecology more closely to classic ecological theory and thinking,” Schimel explains. “So we took

a hundred-year-old idea from plant ecology — how stress and resource gradients structure the diversity and composition of plant communities — to see how it applied to microbes in a soil profile. It’s an incredibly simple question, but it had never been asked before.”

The scientists tracked microbial populations along two gradients in the soil — resource availability and stress — to see where the populations were most diverse. Theory holds that it won’t be at the high end of resources, because a few well-adapted species will dominate there. At the same time, diversity won’t prevail at the low end of resources, because few species can survive there. Maximum diversity, according to the hypothesis, should be found at an intermediate level. Stress should create the same results. Not many organisms can handle very stressful conditions, while a few well-adapted species will dominate areas with very little stress.

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In the soil, the resource gradient is highest near the surface, where there are lots of nutrients and organic matter. But stress is also high near the surface — temperatures fluctuate dramatically, moisture varies rapidly, and the soil can even be physically disturbed. In deep soils, on the other hand, both stress and resources are low. There is little organic matter, but temperature and moisture are relatively constant, and the soil is seldom disturbed.

So where's the point of highest microbial diversity? Using a DNA fingerprinting technique that can pick up 100 or so dominant species (as opposed to the thousands of minor species), Michael LeMontagne, a postdoctoral researcher working on the project, found that the pattern in microbial communities reflected the classic hypothesis perfectly. "I was really surprised," Schimel recalls. "Our data suggests that there is a peak of bacterial diversity about 20 centimeters down in the soil profile, even though the biomass of microbes drops off very rapidly from the surface."

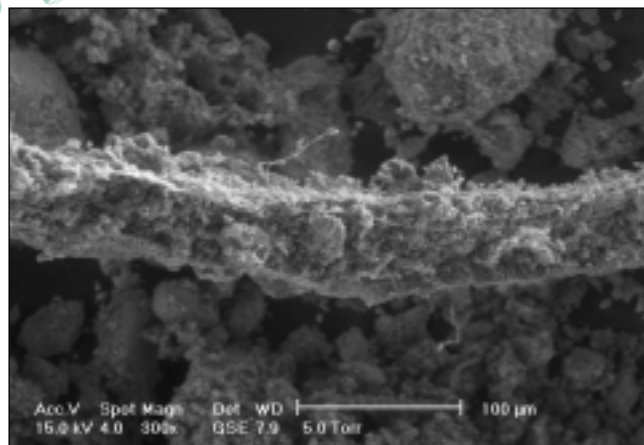
While species abundance declines dramatically after 20 centimeters, Schimel

stresses that the deep soils should not be ignored. "In surface soils, you can get enough DNA to work with from one-tenth of a gram of soil. At 4 meters, you need 100 grams of soil, and you still need to amplify it before you can analyze it. There's not a lot of life down there, but there's a lot of

mass. When you add it all up, about a third of the total biomass is down below 50 centimeters."

Schimel's estimates match a recent study published in the *Proceedings of the National Academy of Sciences* that estimated there is more biomass in deep subsurface environments — marine sediments and deep soils — than there is in the entire surface world, yet almost nothing is known about these environments.

The study of microbes in their environments is just getting underway. Ultimately, knowledge of this unseen world will lead to greater understanding of more-familiar surface environments. Already, for example, Schimel's



How Sedgwick Reserve looks through the electron microscope: fungus growing across a soil particle, fragments of organic matter, and, probably, bacteria coating the soil particles. Photo by Jose Saleta

team is collaborating with other researchers at Sedgwick to understand how invasive species affect the microbial communities in the reserve's soils. How much of the invasive process is due to changes in soil microbial processes? How sensitive are the microbial communities to plant composition?

The protected environment at Sedgwick is critical for these studies. "One of the problems with terrestrial research," Schimel notes, "is that terrestrial ecosystems change slowly over time, so when you set up an experiment, you need to be able to monitor it over time. At Sedgwick, you can set up an experiment and be confident that it won't turn into a housing development next week." — JB

SNARL — Depths plumbed at Mono Lake

Nestled in the eastern flank of the Sierra Nevada on the edge of the Great Basin, Mono Lake looks otherworldly with its tufa towers and volcanic islands. The impression is widely shared. The unique composition of the lake's waters and geochemical processes prompted NASA to propose it as a potential model for oceans that once existed on Mars or for Earth's own early oceans.

Mono is a terminal lake. Freshwater streams flow into it, but none exit. Water is lost only through evaporation, a process that leaves behind small amounts of salts and minerals leached from the surrounding mountains. During the lake's 760,000-year existence, 280 million tons of dissolved salts have accumulated there, making Mono Lake two to three times saltier than any ocean. The water is rich in carbon, ni-

trogen, sulfur, and arsenic, and is very alkaline, giving it a soapy or slippery feel. This rich chemical brew is warmed, and periodically super-heated, by underlying volcanic activity. Microbial action in the warm, deep sediments accumulated on the lake floor generates methane gas that bubbles to the surface.



No fish can survive in the lake, but algae flourish, as do billions of *Artemia* (brine shrimp) and alkali flies. These prey attract large numbers of birds, both nesting (such as California gulls and snowy plovers) and migratory (such as eared grebes, Wilson's phalaropes, and red-necked phalaropes). Microbes also thrive in this environment and play a crucial role in the lake's geochemical processes.

Many researchers have worked at Mono Lake over the years, but few know it as well as UC Santa Barbara scientist Bob Jellison. From his nearby base at the NRS's Sierra Nevada Aquatic Research Laboratory (SNARL), Jellison has been studying the lake for almost two decades. "As a grad student back in 1982," he recalls, "I was interested in modeling the Mono Lake ecosystem. But once I started doing the modeling, I realized we didn't know enough about the system. So, for eighteen years, I've been doing limnology, figuring out what's going on."

Year in and year out, month after month, Jellison ventures out onto the lake to collect data. "I've been studying plankton dynamics at the lake since I started my dissertation research, so I'm interested in primary production, nitrogen cycling, and *Artemia* population dynamics. Along with that, I've maintained a long-time series of physical, chemical, and hydrological characteristics of the lake."

Jellison's detailed monitoring has created a record unmatched for any other of the world's salt lakes. This valuable record was one of the reasons the National Science Foundation established a microbial observatory there. The limnological data kept at SNARL provides the environmental background for researchers' more directed studies. Relatively little work, for example, had been

done on bacteria at the lake, leaving an open niche to investigate an interesting, well-characterized habitat.

Jellison is pleased with this new area of research. "The microbial observatory team is really complementary," he says. "Samantha Joye, from the University of Georgia, is a geochemist looking at methane cycling in the lake. Tim Hollibaugh, also from the University of Georgia, focuses on the arsenic cycle and the phylogenetic questions in terms of what microbes are there and what they're doing. Jonathan Zehr from UC Santa Cruz is an expert in nitrogen fixation. And Sandi Roll and I are looking at the phytoplankton." The work has also attracted a number of other scientists doing related research, including Sally McIntyre (UC Santa Barbara), Sunny Jaing (UC Irvine), Ron Oremland (U.S. Geological Survey, Menlo Park, CA), Johannes Scholten (University of Warwick, England), and Heide Schulz (University of Hanover, Germany).

"Microbes are another piece of the puzzle," Jellison explains. "Mono Lake is hypersaline, very productive, permanent (most salt lakes are shallow, intermittent playas), and fairly deep (averaging about 45 meters), so there are a lot of vertical gradients in the

water column. Within these sharp gradients in the physical and chemical conditions, microbial populations find various niches. That makes it very interesting to study."

Tim Hollibaugh, one of the project's principal investigators, worked at Mono Lake in the 1980s and finds SNARL's facilities crucial to the current work. "Most salt lakes are in remote regions far from any facilities. The last time I worked at Mono, I had to set up a lab in the Best Western in Lee Vining," he recalls with a laugh. "A lot of the geochemistry we're doing needs to be done on site, and with the reserve nearby, we can take samples, do

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Microbe sampling at Mono Lake: (top) Scientists Robert Jellison and Sandi Roll out on a routine monthly "field" trip. Photo courtesy of Robert Jellison; (bottom) Jellison with a freshly collected sediment core in his lap. Photo by Sandra Roll

Microbial observatories

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experiments, go back day after day to look at temporal variations, or follow processes in the lake as a result of either manipulations we've made or natural events."

"It all fits together," Hollibaugh continues. "We need to know how the microbes are interacting with the rest of the lake environment. For that, we need either specific measurements of different kinds of rates, like sulfate reduction or arsenate reduction, or measurements of changes in the chemical composition of the water. For example, in the arsenic work I've been doing, we've been looking at change in the form of arsenic in the lake through time as the lake goes through its annual cycle."

Life in the Lake

The microbial observatory is now in its third year of operation. The team has already produced seven papers and has several more in the works. Its approach has been to employ molecular biological techniques to identify the lake's microbial community, then apply specific genetic tests to ask questions about what kinds of processes that community generates.

Distribution of microbes is controlled primarily by the lake's stratified chemistry. One group lives in surface water where there is oxygen, light, and active plant growth. Another group, the anaerobes, lives near the lake floor where it's dark, devoid of oxygen for years at a time, and filled with high concentrations of sulfide and ammonia. A third group lives where the oxygen begins to disappear. They derive energy from the oxidation of sulfide, ammonia, and organic carbon that diffuse up from the lake bottom.

The unique chemistry of Mono Lake's water has produced an equally unique microbial population. With the increasing use of naturally occurring microbes in industrial products and processes, Hollibaugh is optimistic that there might be similar applications for those found in the lake. He says, "The lake's high pH has significant implications for how the bacteria's biochemistry works: it makes it hard for their biochemistry to work, so it selects for those organisms that can adapt. A lot of chemical processes take place at a high pH, so extracellular enzymes that are stable in the lake could be useful in certain kinds of processes that might have industrial applications."

Mono Lake's high levels of arsenic may also prove valuable. "The arsenic is naturally occurring," Hollibaugh explains, "but its concentrations are higher than in any other natural environment. And arsenic is an active part of the geochemical cycle of the lake, so there are bacteria that transform it as a regular part of doing business. Arsenic and selenium have very similar geochemistries, so many of the bacteria that transform arsenic also transform selenium. The work we're doing may have applications for contaminated aquifers or in irrigated areas where selenium buildup is a major problem."

Entering a New Phase

Mono Lake's stable, stratified environment has provided relatively stable niches where researchers can identify microbial species and investigate their role in the lake's geochemistry. Whereas the water in most lakes "turns over" once or twice a year, with oxygen-rich surface waters mixing with nutrient-rich deeper waters, Mono Lake has remained nonmixing, or meromictic, since 1995. Heavy snowfall in the win-

ter of 1994-95 and the curtailment of water diversions to Los Angeles led to a huge inflow of fresh water that flowed over on top of the deeper, saltier waters.

But this stability soon may be coming to an end. Jellison's models predict that the past three years of below-average rainfall will shortly bring about a change. "Lake levels have declined," he explains. "Meromixis* and the chemical stratification are weakening. We just did a forecast, and the lake is going to come very close to turning over this fall [of 2002]." [**Editor's note: A meromictic lake is one with a stably stratified water column maintained by a density gradient caused by chemical stratification.*]

If the lake does mix, most visitors will notice few changes — the brine shrimp will die off in greater numbers than usual and the odor of hydrogen sulfide will permeate the air for a few days. But microbial ecologists will find the world they've been studying for years turned on its head, at least until the waters reach a new equilibrium.

Hollibaugh greets the anticipated turnover eagerly as a new opportunity to learn more about the lake. "It's going to dramatically alter the distribution of these bacteria. We're going out in November, when this is likely to get underway, take samples, and if it looks like [the turnover] is actually going to take place — weather or other factors may put it off or make it earlier — we'll mount a special sampling effort throughout the winter."

Jellison is pleased that the team's findings have filled in one of the major unknowns about Mono Lake. He also hopes the team's work will encourage a research trend he feels was long overdue. "Saline lakes are really coming to the forefront in terms of microbial studies around the world. There's a lot of inter-

est in looking at these saline sites, because they offer such a range of chemistries, salinities, and processes for looking at microbial dynamics. It was about fifteen years ago that people realized what a scientific resource these saline lakes were, and it's only very recently that they've begun utilizing them." — JB

For more information about microbial observatories at Sedgwick Reserve and SNARL/Mono Lake, contact:

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Innovative snowy plover program at Coal Oil Point pays off

Reserves located near populated areas face tremendous challenges balancing environmental needs with public access.

Coal Oil Point Natural Reserve adjacent to the UC Santa Barbara campus is a dramatic example. For three decades, the University community and public had enjoyed unrestricted access to Sands Beach on the reserve for surfing, sunbathing, picnicking, jogging, cycling, horseback riding, and dog walking. The upper beach, however, is home to the western snowy plover (*Charadrius alexandrinus nivosus*).

With a population estimated at 1,300 individuals, the snowy plover has been federally listed as threatened since 1993. And with 80 percent of plover nesting areas destroyed, its numbers continue to drop. While the reserve's ongoing population is estimated at 180 birds, none were nesting there in 2000 — nor had they nested there since the University allowed public access to the beach thirty years ago.

After a study by USGS biologist Kevin Lafferty revealed that beachgoers, both human and animal, were constantly disturbing the snowy plovers, Reserve Director Cristina Sandoval developed a

management plan to help the birds. Rather than simply exclude public access, she set out to change the visitors' behavior. Trails were rerouted around potential nesting areas, signs were posted with explanatory maps and reminders to keep dogs on leash, and fences were installed to keep people and animals out of the sensitive upper beach.

The key to the program, however, was the involvement of more than 70 docents recruited and trained by Kendy Radasky and Jennifer Stroh of the Audubon Society. These docents now patrol the beach every day from dawn to dusk, watching over the plovers, educating beachgoers about the tiny birds' presence, and asking everyone to respect the boundaries of their nesting area. They even set up a spotting scope so visitors can get a closeup view of the birds from a noninvasive distance.

The program has succeeded well beyond anyone's expectations. Although only one chick was hatched in 2001, the year the program started, the numbers jumped dramatically this year: 21 eggs were laid, 16 chicks were hatched, and 14 fledged. Sandoval's program is now considered a model for similar areas that must balance human and environmental needs. — JB

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Snowy plover at Coal Oil Point guards hatchling and egg (above), while visitors watch from a distance (right). Photos by Larry Wan



Educational programs thrive at Stunt Ranch Reserve — even with sky for roof and earth for floor

When Ken Norris was developing his concept of the NRS in the early 1960s, one of his primary intentions was to protect a range of natural environments for teaching and research. Norris was then a young assistant professor at UCLA with a passion for taking his students out of the classroom to study “the real world.” But Southern California’s rapid development was forcing him further and further afield in search of study sites.

Today nearly four decades later, large tracts of open space in the Los Angeles basin have virtually disappeared. Yet thanks in part to the Norris vision, one area in that region remains dedicated to education and research: the Stunt Ranch Santa Monica Mountains Reserve, which joined the NRS in 1995.

This is a convenient reserve, located just a short drive from the UCLA campus and therefore ideal for day trips. And, though it’s situated close to urban and suburban developments, the reserve is contained within the relatively pristine Cold Creek watershed and offers a variety of habitats for research and learning. Furthermore, the reserve’s 310 acres provide access to other parts of the Santa Monica Mountain ecosystem. The surrounding open space — owned by the National Park Service, the state Department of Parks and Recreation, the Mountains Restoration Trust, and the Santa Monica Mountains Conservancy — represent almost 1,500 additional protected acres for instruction and research.

Having such a place as the Stunt Ranch Reserve so close at hand opens up a host of opportunities:

For professors and undergraduates at UCLA and other local colleges and universities, the Stunt Ranch Reserve is a field teaching site readily available for classes in subjects such as conservation biology, geology, ecology, archaeology, geography, and astronomy.

For research scientists, the reserve provides unparalleled opportunities to investigate animal behavior, Mediterranean ecosystems, air pollution, wildfire dynamics, and other topics of critical importance to the region’s public policymakers.

For the entire University community — alumni, faculty, staff, and students — it’s a place to escape the campus bustle for departmental meetings, special events, or retreats.

For the thousands of K-12 students from schools located throughout the Los Angeles area, Stunt Ranch Reserve is a very different sort of place to attend classes and, often, is their first introduction to life outside the urban environment.

However, what is perhaps most amazing about the reserve’s current program is how it somehow manages to serve all of its audiences *without* permanent on-site facilities. In 1993, an arson-set wildfire swept through the area, destroying all buildings on site, including a small nature center and a cabin built in the 1880s by the Stunt family, the area’s first homesteaders.

Making do with sky and earth

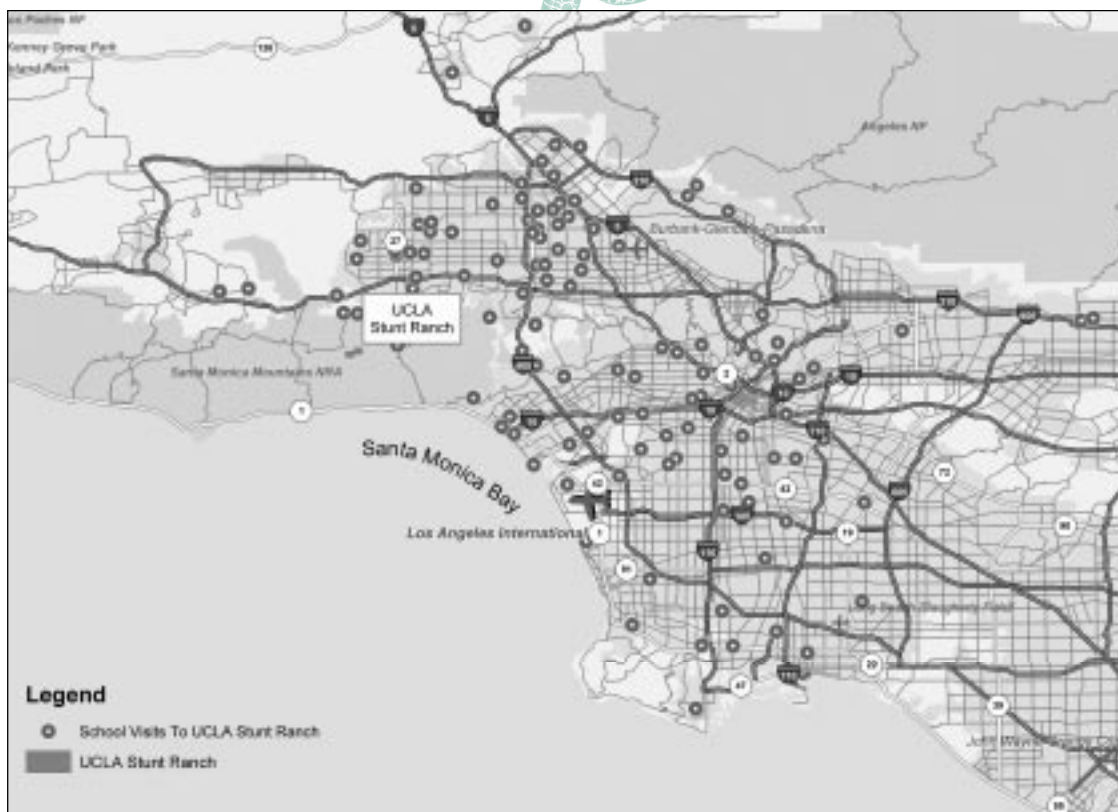
This site is both so valuable and so valued that people have learned to carry out their instructional and research projects without facilities. Professors haul in all of their equipment for field classes and pack it all out at the end of the day. Researchers sit in their cars, entering field notes into their

computers, then carry specimens back to campus for processing or further study. Rain or shine, lectures and discussions take place outside, perhaps under one of the site’s giant oaks.

Lack of facilities hasn’t diminished the popularity of the reserve’s K-12 educational programs, either. The site plays a key role in UCLA’s efforts to maintain a partnership with local schools. Each year, more than 3,000



For two decades, Director of the Cold Creek Docents Nancy Helsely has been instructing schoolchildren visiting Stunt Ranch Reserve about the area’s ecology, geology, and anthropology. Photo courtesy of Cold Creek Docents



This map shows the locations of the more than 150 Los Angeles-area primary and secondary schools that sent students from 1995 through 2001 to the Stunt Ranch Santa Monica Mountains Reserve to attend environmental education programs presented there. Map courtesy of UCLA Government and Community Relations

students from dozens of schools throughout the greater Los Angeles area (see map above) visit the Stunt Ranch Reserve for programs run by the Cold Creek Docents on chaparral ecology, early Chumash culture, and geology.

These programs represent a unique and highly successful collaboration between UCLA, the reserve's administering campus, and the Cold Creek Docents, a volunteer group that has led education programs on the site since 1983. Carol Felixson, UC NRS Director of Education and Outreach for the reserve, explains this symbiotic relationship: "It's good for everyone. UC benefits from the ongoing excellence of the program and the commitment of the docents. The docents receive UC help in putting curriculum guides online, helping to publicize the programs, and providing enrichment opportunities."

Felixson herself plays a key role in keeping the reserve and the education program in the news with regular *Los Angeles Times* features for young readers in the "Kids' Reading Room." Recent articles have looked at rattlesnakes, ants, chaparral ecology, and the area's early homesteaders. Felixson is currently working on a regular series of articles for the

Los Angeles Times as part of the paper's high-profile "Reading by 9" literacy program.

The real winners of this cooperative arrangement are the kids who attend the programs. "A majority of them are from the inner city, and they're used to a challenging urban lifestyle," notes Felixson. "When they first arrive at Stunt Ranch Reserve, some are uncomfortable or even frightened by the open space, the mountains, the chaparral, the idea that there are rattlesnakes or mountain lions out there. But by the time they leave, they're like seasoned veterans of the out-of-doors with a new sense of the importance of resource conservation."

Nancy Helsely, director of the docent program, credits the site: "The Cold Creek watershed is ideal for teaching, because of the diversity of plant and animal life, and the number of natural communities that bump up against each other here. It has a perennial stream, so you have great diversity of wildlife. Much of the nearby habitat is also protected ... and it's all contiguous, so many animal species thrive here."

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Stunt Ranch thrives

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Area teachers love the reserve, and many make annual visits as part of their curriculum. But they also emphasize the role the docents play in bringing the environment alive for their students. Pamela Kerman, a second-grade teacher at L.A.'s Curtis School, has been bringing classes to the reserve for six or seven years. She says: "It's one of the highlights of the school year for all three of our second-grade classes. The docents are so knowledgeable. They take the kids on hikes and always find something interesting. If they come upon animal scat, they'll tell you what animal it's from, then break it open to show you what the animal ate the day before. Or they'll cut open a gall and show the baby wasp developing inside."

Kerman is especially impressed by the docents' Chumash program. "Our second-grade curriculum focuses on Native Americans, and the program at Stunt Ranch really brings the Chumash alive. The docents have built a replica Chumash village with traditional houses made from bent willow branches and tule thatch. This makes it easy for the students to see how the village reflects the local environment. They also show the kids a number of artifacts that were found on the site. From these, the kids see that the Chumash were not farmers; they were mostly hunters and fishermen, who also gathered acorns and seeds for food."

"The entire program is participatory," Kerman explains. "There are grinding stones where the kids can grind acorns. They can make soap from soap lilies, do sand paintings,

and play Native American games. The kids see how the Native Americans wasted nothing. They used every part of the animal. And the docents reinforce that this is still important today — they make sure the kids bring out everything when they leave!"



New facilities at Stunt promise four-season science

Nancy Helsely directs the Cold Creek Docents, who have been leading education programs at the Stunt Ranch Santa Monica Mountains Reserve for over twenty years. She is excited about how this NRS reserve's new facilities will allow the docents to better serve students. "For one thing," she observes, "we'll be able to hold programs in any kind of weather. Right now we have to cancel programs when it rains. Each morning we try to second-guess the weather. And when it does rain, it's a major hassle for the teachers because they have to cancel the buses at the last minute. We'll definitely be able to expand the current program with the workroom and exhibit areas."

Plans completed for new facilities

With the enthusiastic support of UCLA faculty and students, local educators, and neighboring natural resource management groups, architects have drawn up plans to build new facilities that will be flexible enough to support all of the reserve's teaching, research, and outreach programs. The final design minimizes the project's impact on the land and, insofar as possible, reflects the site's original homestead architecture.

The master plan includes an education/nature center that can be used for both research and teaching, as well as a residence/office for facilitating the site's day-to-day management. UCLA and the NRS systemwide office are providing roughly half of the budget; private donors are being sought for the remaining funds needed to complete the project.

Construction will be divided into two stages. Phase I will focus on infrastructure improvements and the education/nature center. The center will feature a classroom for up to forty students and a small museum area where visitors can explore exhibits on the cultural, natural, and dynamic landscapes of the Cold Creek watershed. Out-of-doors, students and other visitors will find a wheelchair-accessible, night-lit nature trail with native plant displays and a replica Chumash village. Noted botanical illustrator Lisa Pompelli is playing a key role in developing these exhibits.

Both researchers and students will benefit from the nature center's large workroom, where they can use microscopes and other equipment to study and prepare specimens, and

safely store tools and equipment in locked cabinets. Restrooms and a small kitchen complete the facility.

Phase II of the project will provide the office/residence for a manager who will oversee on-site activities and scientific programs for the reserve. — *JB*

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This artist's rendering envisions the new facilities at the Stunt Ranch Santa Monica Mountains Reserve. Illustration courtesy of UCLA Facilities Management

In Memoriam —

Galen Rowell

August 23, 1940 – August 11, 2002

When world-renowned photographer and mountaineer Galen Rowell and his wife, Barbara, died in a small-plane crash this past August, it was a great loss for all people who love his splendid photography and the wild places of the world that he documented so beautifully for thirty years. Galen's passing was also a personal loss for the NRS. Nearly twenty years after the fact, we still regularly publish the slides of NRS reserves that he took for us on assignment back in 1983-84 when we were preparing our twentieth anniversary report. His images are timeless, eternal. And his generosity in allowing us to reproduce them in our publications year after year lives on in support of the NRS. We are sorry to lose a great artist and friend. — *SGR*

Galen Rowell on assignment for the NRS in 1984, at Landels-Hill Big Creek Reserve, Big Sur. Photos by Jeff Kennedy



Midwest undergrads spend a month at six NRS reserves, getting grounded in field ecology and in themselves

If you ask field ecologists why they pursued their discipline, the majority will cite memorable field-based courses. Field classes, taught at remote sites or out of vans, were chockful of impromptu trailside lessons where students not only learned ecological concepts, but also participated in scientific research projects. My belief in the power of experiential learning was reinforced by my own experiences as a graduate student at the NRS's Bodega Marine Reserve, and now I enjoy working at an institution that values this approach.

I teach at a liberal arts college called Gustavus Adolphus in St. Peter, Minnesota. Each January, my colleague Charles Pastor and I offer a one-month intensive field course called the *Natural History of California*. For the past three years, we have taken thirteen undergraduates to explore desert and coastal ecosystems using six UC NRS reserves. For twenty-five days, we live and learn together, gaining a more complete picture of one another's academic and personal lives. Barriers common to classroom learning disappear in the field.

Our students have traveled little beyond the upper Midwest; most have never seen the Pacific Ocean or walked in a desert. Minnesota's rich farmland and abundant water have shaped their view of resource issues. They enroll in the class eager to understand the biological and cultural complexity

of their nation better, while learning more about ecological research and environmental stewardship.

Each of the six NRS reserves we visit becomes a living laboratory displaying components of California's unique natural history. We focus on the following questions:

- (1) What are the dominant species characteristic of each area?
- (2) What environmental factors shape adaptations?
- (3) How have people, in prehistoric times through contemporary times, utilized resources in each system?
- (4) How does resource availability affect conservation attitudes in each area?

Students read and participate in discussions about environmental ethics and conservation. Connections are built when reserve managers, directors, stewards, and affiliated professors talk about regional issues related to development, grazing, restoration, invasive species, and fishing. Our students respect the commitment of reserve personnel to various regional environmental causes. What follows is a travelogue, a description of our activities on the six NRS reserves told by fusing journal entries from both students and professors.

— Pamela Kittelson, Instructor
Gustavus Adolphus College, St. Peter, Minnesota

January 2002
Natural History of California
Gustavus Adolphus College,
St. Peter, Minnesota
Instructors:
Pamela Kittelson and
Charles Pastor

Sweeney Granite Mountains
Desert Research Center (1/8-11)

We are at Norris Camp, nestled at the base of rosy, granitic spires on the north side of the reserve. Before making camp, we stopped to hike on Cima Dome, a giant curved

batolith covered with a stalwart lily, *Yucca brevifolia*, commonly known as the Joshua tree. We spent yesterday in the neon glitz of Las Vegas and visited the impressive engineering feat of Hoover Dam. The juxtaposition of desert reality and America's "needs" provided a good preface to our discussion of water issues in the West.

Today we hiked six miles through a pass in the Granite Mountains. This was the hardest hike I have ever done in my life, but the expansive view of the surrounding desert was lovely. Our destination was Granite Cove, where we learned about the reserve, the unique regional flora and Mojave natural his-

tory from [reserve director] Jim André and [assistant reserve director] Jason Sexton. [Reserve steward] David Lee gave a captivating description of Native American culture and archaeology. We climbed into caves filled with pictographs, saw darkened soil hearths, primitive stone tools, and other evidence of people who existed here only 300 years ago. What did these signs mean? Will my generation leave mystery or disdain?

It is so quiet at the Granites, it is rare in our world to be in such a silent place. It is awe-inspiring, yet humbling. I take much for granted

in my daily life, simple things like water. I am from the fertile Midwest and forget that dry places exist where only the hardiest of species survive. Harsh desert conditions shape amazing adaptations for persistence: spines, venom, long tap-roots, irritating fibers all made to protect or acquire one thing — water.

The climb to the top of Kelso Dunes was tough, since the sand slid down with every step. We were able to make the dune produce a low-pitched hum by sliding down it. The sound was caused by the agitated, vibrating top layers of sand sliding over the stationary layers underneath. Only about 30 dunes in the world have this effect.

Burns Piñon Ridge Reserve (1/12-16)

When we approach the home built by Mr. [Bruce] Burns [who, along with his wife, Jean, donated the land for this reserve to the University], an excited murmur passed through the van. Convinced we might have to “rough it” for the whole month, we are now faced with architectural comfort; the fireplace, deck, bathrooms, and extensive kitchen are an oasis. The best of both worlds exists at Burns: the ruggedness of the outdoors and comfortable beds. The carpet brought us closer together as a group.

[Reserve manager] Bill Bretz and [UC Irvine academic coordinator]

Peter Bowler discussed development, mitigation, and restoration in southern California. Then we helped them pull several truckloads of South African iceplant from the garden surrounding the house. It is great to know that native xeric landscaping will replace exotic. [Reserve steward] Brad Berger showed us the entire reserve, focusing

ered commensalistic and maybe even parasitic, but could they ever evolve into symbionts?

My associations with California were with the green, marine areas of the state. The desert never came to mind. But now I have gained an appreciation for the desert while at

Burns Piñon and the Granites. There are so many research questions that remain unanswered here.

Ventura (1/17)
Santa Cruz Island
Reserve (1/18-20)

Santa Cruz Island looked like Jurassic Park from the boat, with wisps of fog and steep green cliffs with birds flying everywhere. Once we docked, we rode in what appeared to be a rickety old truck, but it was a trooper on the rugged roads. We increased the human population of the island to twenty-five! It was an amazing change from the desert. You close your eyes and feel the cool sea breeze on your face and smell verdant plants. However, [Reserve Director] Lyndal [Laughrin] taught us that many of the plants are non-native and that roaming herds of

wild pigs decimate huge areas of native vegetation. Over three days, we saw island endemics everywhere, gigantic *Coreopsis* and dwarf foxes, and I could “see” the evolution of the cobalt scrub jay and Santa Cruz Island pine in isolation. On the way



Field course students Jim Eckberg and Phil Graeve filming reptiles at Burns Piñon Ridge Reserve.



Walking Kelso Dunes near the Sweeney Granite Mountains Reserve.

on the reptile sampling methods of the last steward, Robb Hirsch. I started thinking about symbioses, especially when we learned about the interaction between Joshua trees and *Tegeticula* moths. Then I started noticing galls on other plants, reconfigured plant tissue that is home to obscure species of flies and wasps. The insect galls are consid-

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Midwest undergrads

Continued from page 13

back to the mainland, it was wonderful riding on the boat with barnacled whales breaching all around and dolphin pods breathing in leaps. The sun was setting and the sky turned pink, orange, yellow, and slate blue. After some experiences, you just are content.

Kenneth S. Norris
Rancho Marino Reserve
(1/21)

[Reserve manager] Don [Canestro] and Miranda [his wife] were so enthusiastic and welcoming. We waded into the intertidal, picking up urchins, snails, sea stars, limpets, brittle stars, brown and red algae. I never knew so much life could live in such a small area. We “hunted” for red-legged frogs with our headlamps and heard all about sea otters from Jason [Hill], a field technician. The next morning we traveled up the coast to see where he was observing otter behavior. We also visited the elephant seal colony, where hundreds of female seals haul out to have their pups under the watchful eye of the giant males battling for harems. I was impressed with the diversity and various ecosystems that Norris Rancho Marino offered — from intertidal to Monterey pine forests (an endemic!). I also was amazed to learn that some grazing helps this system by controlling the non-native grasses.

Landels-Hill Big Creek Reserve
(1/22-26)

Big Creek was dreamlike from the second we pulled through the wrought iron gates shaped like crashing waves. The conversation in the van ceased entirely. The redwoods towered taller than our necks could crane. Ferns and lush vegetation fill the canyon. Big Creek cascades through the reserve, filled with clean, crystal clear water. Thirteen people were glued to the win-

dows as we wound up and up, past the tallest redwood and into the coastal scrub and chaparral. Our “home” is located on a cliff that is perched 1,000 feet above the ocean. [Editor’s note: *Actually it’s only 600 feet, but seems higher.*] The crimson and amber sunset with gnarled oaks above me and redwoods towering below me, punctuated by the ocean slamming into the coast, created an area of perfect beauty unsurpassed by anything I’ve experienced.



Field course students tour Santa Cruz Island *en plein air*.



Leslie Brandt, Gustavus Adolphus student in the January 2001 field class, journaling at the Kenneth S. Norris Rancho Marino Reserve.

[Reserve manager] John Smiley discussed the marine reserve and how he set up a voluntary research project with the local fishermen. Each fisherman records the sizes of each of the first five fish he catches beyond the reserve boundaries in exchange for boat access to the Big Creek beach. [Editor’s note: *No fishing is allowed within the Big Creek State Marine Reserve; fishing is*

permitted outside the reserve in the Monterey Bay Sanctuary.] While John was talking, a fisherman came to register his catch of orange-red rock cod that had bulging eyes. It was inspiring to hear that Big Creek was one of the few places along the coast that had support from local fishermen when the state decided to make it a marine sanctuary. This gives me hope that people, like those involved with the reserve system, make an impact. This is what Wendell Berry and [Aldo] Leopold wrote about, the land ethic in action, conservationists and local business — our communities — working together to protect resources for future generations.

Hastings Natural History Reservation (1/27-31)

We woke up at Hastings this morning, looked out the window, and saw a winter wonderland. It was snowing! It only snows every five to ten years in Carmel Valley. We watched [reserve director] Mark Stromberg's slide show of California grassland restoration. It surprised me that California learns prairie restoration techniques from the Midwest. It's also amazing that people like Mark love organisms and systems so much that they devote significant time and energy to researching and conserving them. For example, not many people are very fond of grasses. Mark loves oaks and grasses, works to restore native systems, and that is cool.

The reserve system is amazing and inspiring, I feel such a strong connection to each one we have visited. To know that there are dedicated professionals and institutions striving to preserve natural areas for education, research, and conservation gives me hope. To visit these areas and understand firsthand their biological diversity is of far greater educational value than any other method of learning this material. This experience in the Natural Reserve System will help me become a better steward, teacher, researcher, and citizen.

Field course afterthoughts

Before January, I thought California was basically a Barbie commercial.



Backpacking field course students make their way along the steep topography of the Landels-Hill Big Creek Reserve.



An unusual snowfall at the Hastings Natural History Reservation in Carmel Valley.

I thought it was tan blonds driving convertibles among palm trees. These reserves have taught me that California is a region of the continent defined by many things that Barbie does not know and cares nothing about. We learned that California is defined by location, about being sandwiched in between the Sierras and the ocean, defined by millions of years of geologic activity of faults and volcanoes, shaped by the giant sloth and saber-toothed tiger, by the Chumash, the Essalen, Desert people, shaped by the Spanish missions, Manifest Destiny, consumerism, geographic isolation, and the Mediterranean climate. Ultimately, this creates a land that has many regions, climates, vegetations, and natural histories. Cali-

fornia also has taught me through great experiences, classmates, and professors that life is about taking ships, embarking on hikes to the unknown, climbing the hardest route, and kayaking in cold water. Like the waves on the shore, I feel drawn to a vocation that is still a bit undefined, but now I feel more confident that I can and will make contributions to science and my community.

This was an excellent opportunity to step out of my life at Gustavus and gain another perspective. I can think on these reserves. I not only learned a great deal about ecological research and the natural history of California, but I also found myself re-examining environmental issues and deciding how I want to live. I hope for a relatively

humble life, living in a way to leave natural systems intact. I developed my leadership skills and believe that environmental stewardship means standing up for a cause and interacting, in an informed manner, with other people and the surroundings to further that cause.

— *Student journal contributors:*
 Andy Anderson, Derek Boll, Emily Dahlquist, Jim Eckberg, Phil Graeve, Louisa Kempema, Michelle Maley, Mary Panzer, Monica Paulson, Lisa Smart, Sheila Tuel, Erica Wenger, Jeff West

Photos by Pamela Kittelson

A few words

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per milliliter. How many different organisms are there in such a sample? Can we identify some or all? What is each type of organism doing? These microorganisms are part of a complex system. An acre-foot of fertile topsoil may contain more than three tons of prokaryotes, fungi, protozoa, nematodes, algae, and insects. They are indispensable components of food webs and maintain soil structure and aeration. The diversity of prokaryotes (organisms lacking a membrane-bounded nucleus) is far greater than that of larger, multicellular organisms, and the vast majority of the former have yet to be described. A particular habitat may have 5,000 or more different prokaryotes.

The classic microbiological approach is to obtain pure cultures of microorganisms, then study their physiology and biochemistry. However, only a tiny fraction of the organisms in samples such as those described above has been successfully cultured. Consequently, answering the questions posed above had to await the development of culture-independent approaches. This has now been achieved, at least in principle. New methods of molecular genetic analysis, along with

a variety of advances in analytical techniques for the separation, detection, and characterization of small molecules, in microbiology, biochemistry, and bioinformatics, enable the identification of microorganisms and their functions in complex assemblages of organisms.

Recognizing these new capabilities, the National Science Foundation (NSF) initiated *The Microbial Observatories Program*. "The long-term goal of this activity is to develop a network of sites or 'microbial observatories' to discover novel microorganisms, microbial consortia, communities, activities and other novel properties, and to study their roles in diverse environments (<http://www.nsf.gov/pubs/2002/nsf02118/nsf02118.htm>). To date, the NSF has funded thirty microbial observatories. One of these, at the Sedgwick Reserve, explores microorganisms in a soil profile 4 to 5 meters deep. A second, based at the Sierra Nevada Aquatic Research Laboratory, focuses on nearby Mono Lake, an alkaline, hypersaline, stratified lake (<http://www.monobasinresearch.org/research/microbial/>). The stories in this issue offer glimpses of the functioning of microorganisms in these two very different habitats.

— Alexander N. Glazer
Director, Natural Reserve System



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