Over the past 50 years, Earth-observing satellites have transformed the way we think and what we know about our planet. Continuous observation of Earth from space started in October 1957, initiated by the Soviet Union’s launch of the world’s first satellite, Sputnik. The United States followed soon thereafter, launching Explorer 1 in January 1958 and Explorer 3 in March 1958. These satellites promptly provided the first major scientific discovery of the Space Age—evidence that intense bands of radiation surround the Earth (now called the Van Allen radiation belts).

Geostationary satellites enabled continuous weather monitoring—another great early achievement. We have become so accustomed to this

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Sensor networks at NRS reserves pioneer new ways to observe Earth

Throughout history, humans have searched for new ways to view the Earth and better understand its natural processes. Just as the earliest microscopes and telescopes extended our vision into previously unseen worlds, other technologies have had equally profound impacts. In the 1840s, the quest for a new perspective led some scientific explorers to send aloft still-cameras tethered to balloons in order to document an expanse of forest or city. Aerial photography from airplanes became common in the 1920s and ’30s, capturing images of large swathes of the planet’s surface. By the middle of the twentieth century, breakthroughs in space sciences raised to new levels our ability

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to view the Earth. The first weather satellites dramatically improved our ability to detect destructive storms and predict their courses. The 1972 launch of Landsat 1 ushered in a new era of multispectral observations that include visible light, near-infrared, mid-infrared, and thermal data. Today these satellites are tracking everything from typhoon destruction in Burma, to pollution plumes in Chesapeake Bay, to the retreat of Alaskan glaciers, to water-consumption patterns in the western United States.

As impressive as these accomplishments are, the laws of physics cannot be defied. As one's distance from an object increases, the ability to detect fine details diminishes. Remote sensing — identifying, observing, and measuring an object without coming into direct contact with it — has its limits. Engineers and environmental scientists have continued to search, with their feet on the ground, for ways to monitor natural processes from the Earth itself, without taking to outer space or even aerial space. The explosion of computer and networking technology in the 1990s has now put us within reach of this goal.

Today networking technology, pioneered by engineers and scientists working at NRS reserves, is playing a key role as we enter a new era of global discovery through monitoring. Networked-sensor technology prototyped, field-tested, and refined at the James San Jacinto Mountains Reserve in Riverside County has provided the basis for systems that monitor everything from local microclimates to continental climate change. Technology from the same reserve is now being assembled in Central America to support investigations into carbon flux in tropical rainforests. And sensors originally developed to monitor the elephant seal population at the Año Nuevo Island Reserve in San Mateo County have evolved to track the animals into the open ocean and reveal, for the first time, the rest of their life stories. These same sensors are also providing dramatic new insights into the functioning of the oceans themselves.

Within the NRS, sensor networks are proliferating. At Angelo Coast Range Reserve in Mendocino County, scientists from the Keck HydroWatch Project are using a wireless network to monitor a watershed’s response to rainfall without leaving their offices in Berkeley. At Quail Ridge Reserve in Napa County, scientists plan to use the reserve’s innovative wireless mesh network to monitor frog and bird populations. And at Sagehen Creek Field Station in Nevada County, a recently installed series of 13 towers will provide a broadband, wireless communications system for scientists working throughout the 8,000-acre watershed.

The CENS Story

At first glance, the newly established Blue Oak Ranch Reserve in the Mt. Hamilton range above San Jose would seem more notable for its natural beauty than its technological potential. Aside from the array of solar panels on the roof of the barn that serves as the reserve’s temporary headquarters and a single weather and communications station on a nearby hilltop, technology appears to play a secondary role here.

But walk the hills with Reserve Director Mike Hamilton and he paints a very different portrait. Climbing the steep
hillside to the weather station, he explains: “We call this the Alpha Node. It’s a solar-powered weather station, but it’s also a wireless relay point that links the Lick Observatory [owned and operated by UC and located on nearby Mt. Hamilton]* to a directional Wi-Fi radio that points down to the barn, providing us with Internet access. And this omni-directional antenna plugs into the router on the tower to create a large Wi-Fi cloud on the top of the hill that’s strong enough to get a signal down to the pond and the stream at the foot of the hill, so researchers will be able to monitor these locations using portable wireless environmental sensing systems.”

*No connection to Reserve Director Mike Hamilton, despite what he claims.

Obviously, Hamilton is comfortable speaking as both an ecologist and an engineer. From 2002 through 2007, he served as a principal investigator for the Center for Embedded Network Sensing (CENS), a National Science Foundation-funded Science and Technology Center based at UCLA and involving faculty from university campuses throughout Southern California. At the time, Hamilton was director of an NRS reserve administered through UC Riverside, the James San Jacinto Mountains Reserve, where many CENS concepts were field-tested.

Now in its seventh year, the CENS Project has had a major influence on ecological observatory networks throughout the world. “It’s such a huge field of integration of interdisciplinary science between engineers and computer scientists and environmental scientists,” notes Hamilton. “It seems that everyone is doing sensor networks today, and a lot of what they are doing is based on the work we did at the James Reserve. We’ve essentially provided the specifications for how to do things. Deborah Estrin (Director of CENS) has always had a very open-source approach to the computer code, and the details of how to build our systems are all published either in our own reports or in other publications. Over a thousand publications came out of CENS — and the James Reserve has a credit in many of them. We have an astounding publications record in that area of science.”

Concepts pioneered by CENS have influenced the ongoing development of the National Ecological Observatory Network (NEON), a continental-scale research platform for discovering and understanding the impacts of climate change, land-use change, and the encroachment of invasive species. Tentatively scheduled to begin operation in 2013, NEON will include 20 fully instrumented ecological observatories across the country, as well as mobile instrument packages that can be moved to areas of special interest. All of these data sources will be linked by an advanced cyber-infrastructure designed to record and store data for the next 30 years. Hamilton and Estrin both served on the NEON technology committee that helped to establish the types of technology that would be used at each NEON locale.

“We were involved in the original prototyping design of what NEON should become,” Hamilton explains. “Our committee solicited input from hundreds of ecologists, the potential end-users for NEON. We realized that all major NEON sites would have sensor networks associated with them, as well as large instrumented towers that would measure CO₂ fluctuations very precisely to provide a sense of an ecosystem’s productivity, how it breathes. Our job was just to develop the specifications. What did it need to do? What should its major components be? The model numbers, the brands of the systems they select, the installations are still being worked out by contract engineering firms.”

In his new position at Blue Oak Ranch Reserve, Hamilton has the opportunity, and the challenge, of drawing on what he learned at the James Reserve to develop a network from scratch. His

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focus is on reliability and ease of use. He says: “I’m entering this era where I feel we should be getting more into ‘plug and play’ on sensor networks, rather than research and development. Over the last seven years, CENS has worked out many of the engineering ideas. Now it’s really about corporate partners taking those ideas and putting them into products. There’s a lot of growth right now in using sensor systems for precision agriculture, ranging from viticulture to golf course irrigations. Those seem to be the big areas where embedded-sensing and mesh networks are playing out. Our field, ecological monitoring of microclimates across a diverse landscape, is a niche market. But the off-the-shelf systems need to be far more reliable and require less human effort to maintain than the prototype systems that we’ve been working on at the [NRS’s] James, Stunt Ranch, and Quail Ridge reserves, where a small cadre of computer-science students keeps the systems running.”

To encourage the development of commercial systems, Hamilton is drawing on Blue Oak Ranch Reserve’s proximity to Silicon Valley to collaborate on new product development. Two major technology companies are currently installing test systems. “Both Sun Microsystems and Crossbow Technology are deploying small test beds here to show different applications for their tools,” Hamilton explains. “Both groups are interested in relevant applications that they can then sell worldwide. So we’re teaming them with faculty and students from UC Merced to monitor wetlands that support salamander populations by deploying sensor networks to measure the changes in rainfall, soil moisture, water depth, and some of the chemical parameters of the water, such as salinity, that vary across the reserve’s ponds, depending on soil type and water source. They all have different populations of amphibians, and they’re going to be different from pond to pond, so if we can set up these test beds in a few different wetlands, we can do comparisons across the reserve. We also want to test the reliability of the systems because, in the future, the reserves will want to pick those that prove their worth.”

Moving in this same direction, CENS has worked with the Information Sciences Institute (ISI) at the University of Southern California to develop network products based on their research. SensorKits (<http://www.sensorkit.net/SensorKit/SensorKit.html>), their first products, are standardized, flexible, networking systems that can be easily assembled and deployed in a wide variety of environments. CENS and ISI engineers have designed the units to be compatible with a wide variety of commercial sensors and to require a minimum of technical expertise to set up and maintain. Their modular design allows researchers to select the specific sensors they need for their project, connect to a SensorKit system, and literally carry the lightweight, waterproof units to their research locales. The kits are already being used by researchers at sites around the world, from Argentina to China.

Rundel in the Jungle

SensorKits and other CENS technology innovations field-tested at the James Reserve are key to a major sensor network development project now underway at the La Selva Biological Station in northeastern Costa Rica. Owned and operated by the Organization for Tropical Studies, a 63-member consortium of universities and research institutes, La Selva has become one of the world’s most intensively studied rainforests.

As of February 2009, the project had been delayed a few months by logistical problems. Talking over the phone from his Los Angeles home, UCLA ecologist Philip Rundel sounded philosophical: “These things always take more time than you’d like. The towers are being built in Ireland. They have to be shipped across the ocean, make it through customs, and then somebody has to bring them to the field station and figure out how to set them up. The staff are already digging a 500-meter trench from the laboratory to the research site for the electricity and fiber-optic connections.”

Rundel has been involved with CENS from its early days. “I focus on ecophysiology,” he notes, “linking atmospheric processes to ecosystem processes. Sensor arrays are very relevant to our work. But remember, three-fourths of the CENS funding was for engineering. And terrestrial ecology is just one of the four application areas they’re looking at. We’ve really been focused on the technology, and we’re just now getting to the scientific questions.”

When it’s completed, La Selva Rainforest Ecological Portal will feature five interlinked towers with sensor arrays monitoring vertical and horizontal profiles of microclimates within the primary rainforest. Each tower provides a heavily instrumented array that will be directly connected,
for both electrical power and data transmission, to the station's laboratory. Beyond the microclimate sensors there will be a series of pan-tilt-zoom cameras and acoustic sensors arrayed above and within the forest canopy. These cameras can be manipulated over the Internet to allow use by individual reviewers from a variety of research projects. All of the arrays will feed data to servers and hard drives in the station's climate-controlled Sensor Operations Laboratory, where data can flow directly to the Internet.

The architecture for the dense array will blanket a 4-hectare plot from the forest's floor to the top of its canopy.

In addition to sensor nodes monitoring microclimates on the ground, researchers will be able to access the 30-meter-high canopy to collect samples and make observations via three stairway towers and a connecting canopy walkway. “One of the most challenging things in a rainforest is that there’s more diversity off the ground than on the ground,” Rundel notes. “The towers will give us the access we need to study that diversity.”

Beyond providing access for researchers, the walk-up towers, along with two additional radio towers, will be linked with heavy wire cables. NIMS (Networked InfoMechanical Systems) mobile sensors, developed by CENS engineers, will move along these cables, raising and lowering sensors to take atmospheric samples at different elevations within the canopy.

Rundel, who studies ecosystem dynamics and carbon flux at La Selva, is confident that the arrays will provide invaluable new insights. “Though most people think of the tropical rainforests as sinks for capturing carbon emissions from the atmosphere,” he explains, “some recent studies have suggested that this might not always be the case.”

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At La Selva, in particular, the trees aren’t growing as fast as they are in the Amazon, and the rate of tree growth can be correlated with the amount of CO$_2$ sequestered by a forest. Based on the station’s long-term climate records, some researchers have suggested that this difference is due to the fact that current nighttime temperatures in the area are slightly warmer than they have been in the past. And if it’s true that nighttime warming reduces a forest’s ability to store carbon, then the Earth’s warming pattern could accelerate.

A related question that interests Rundel is the role that gaps in the canopy, caused by fallen trees, might play in the amount of CO$_2$ that reaches the atmosphere. In most cases, scientists monitor air turbulence above the canopy to determine how much CO$_2$ a forest is emitting. But Rundel and other researchers suspect that the CO$_2$ and other gases might gather under the canopy and then flow horizontally towards canopy gaps that act like chimneys. This is one of the theories researchers will be able to test once they can monitor the microclimates in these gaps.

The science is exciting, but so are the challenges. “Part of the challenge will be calibrating the equipment,” Rundel notes. “Ants will get into everything, and it’s extremely wet, with nearly 14 feet of annual rainfall. But the staff is excellent. CENS engineers have gone down there to train them, and the systems have proven reliable at the James Reserve through a lot of bad weather. It’s going to be very interesting.”

In association with biologist Barbara Block of Stanford University, Costa was a founding principal investigator for TOPP (Tagging of Pacific Predators, <http://www.topp.org/>). Costa has been a leader in an era of discovery that has, for the first time, revealed the secrets of a host of animals that spend their lives in and above the open ocean. “We knew so little about these animals,” he explains, “our original hypothesis could only have been: does this animal live in the ocean? That was the level of our knowledge. For the elephant seals at Año Nuevo Island, we knew where they bred and reproduced, because that happened onshore. But that was it. When we put the earliest tags on them, we found that some of them went to Japan, because the tag would show up there. But what happened in between was a mystery.”
In addition to revealing the behavioral and migratory patterns of dozens of pelagic species, the sensors have also begun to reveal basic patterns in the ocean itself. “There are usually two phases to animals’ movements,” explains Costa. “Either they’re transitory, or they’re stopping and feeding in places. When they’re transitory, most biologists say there’s not much to observe. But to a physical oceanographer, these data [collected from transitory animal movements] are the most interesting. Unlike the CENS program, which heavily instruments a location, we instrument individual animals and let them describe the environment in which they live.”

“Physical oceanographic data are fundamental to understanding ocean weather,” Costa continues. “The salinity profiles recorded by the sensors are how you measure weather in the ocean. Everybody understands temperature, high pressure, and low pressure in the air. In the ocean, temperature and salinity determinants are the equivalent. Our tags provide these data and so help to fill in some very large gaps in the larger global picture.”

In addition to tracking oceanographic data, the tags also monitor the animals’ physical characteristics. “They’re telling us how hard these animals are working,” notes Costa, “how far they swim, and how they respond. We already know that these animals are adapting to a changing environment. When it’s warmer or colder, they’re further from or closer to shore. That’s the major part of my research: understanding how these animals are responding to the changing ocean. Are they working harder? How hard do they forage? Are the prey patches bigger or smaller? That gets back to baseline, and as we better define the habitat, we’ll have a better framework to interpret what’s going to happen to these animals as the environment changes. We’re defining the physical features of the environment with what they do and where they live, so we’re laying out a baseline for analysis.”

Earlier this year, Costa achieved a career benchmark when he traveled to Isla Lobos in Uruguay to put tags on a population of South American sea lions (Otaria flavescens). “I’ve now worked with six of the seven sea lion species,” he explains. “The seventh is the Japanese sea lion and it’s extinct, so I don’t have plans to tag or take blood samples from that species.”

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Much more than a personal accomplishment, however, Costa’s experiences with the southern sea lion typify his approach to research. Currently, scientists know very little about the lives of the South American sea lions, except for what they could observe from places where the animals come ashore to breed and to bear young. “There have only been only a few papers on their behavior at sea,” notes Costa. “People are unsure whether their population is stable or declining. So we’re trying to find out where they’re going, looking into their diving capabilities. The oceanographic data are really a secondary benefit when we begin looking at a new species. On the other hand, if you combined the data captured by all the sea lion and seal species, we now have oceanographic measurements that cover about half the Earth.”

The success that Costa and dozens of colleagues have had with the TOPP program has exceeded even the most optimistic projections. As part of the global Census of Marine Life, TOPP is beginning to build a picture of the “other” two-thirds of the Earth’s surface. “This wasn’t random,” says Costa. “We had questions we wanted to answer, and we specifically targeted the technology that would give us the data we need to answer those questions. But we still have a long way to go. It’s one thing to collect all these data; it’s another to make sense of them. The challenge now is to collate the data and combine them in ways that are visually accessible. [See illustration below.] That’s our vision.” Just as the James Reserve was a key test bed for the development of the CENS technologies, Año Nuevo Island Reserve has been key to the development of SealNet.

In contrast to their terrestrial colleagues, marine scientists have been forced to rely on sensor technology from the outset. They had no other options. “I think the sheer difficulty of doing what we do has led us to develop technology to a much greater degree than the terrestrial scientists,” says Costa. “We’re studying an animal that moves about the entire North Pacific, so there’s a real difference in the scale at which we’re asking questions. The funny thing about what I do is, I’m asking what happens between here and the Aleutian Islands, but I’m also asking questions at the scale of what happened every hour or at the last two meals. So we are getting both fine-scale and large-scale information, because that’s also the scale over which the animals are living.”

“We know so little about these animals that every opportunity to put tags on them to gather information about them is an incredible opportunity, and even more important in the context of their physical environment. So that’s why I’m so excited about the idea of working with the oceanographers who want these data.” — JB

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Three tracks of southern elephant seals showing the range of data that can be derived after the animals have been tagged. (A) = surface track only; (B) = surface track with underwater behavior; and (C) = track with CT profile along the animals' route (Costa, Goebel, McDonald, unpublished). Illustration courtesy of Dan Costa.
PARASITOLOGIST’S LONG-TERM STUDY OF SMALL SUBJECT BRINGS BIG REWARDS

Kevin D. Lafferty, a U.S. Geological Survey scientist working at the NRS’s Carpinteria Salt Marsh near Santa Barbara, has been chosen to receive the Henry Baldwin Ward Medal for 2009 in recognition of his many years of parasitology research. Lafferty’s investigations have already greatly enhanced basic understanding of how parasites that have complex life cycles interact with man-made environmental changes. It is expected that this deepened understanding will enable humanity to anticipate future changes in parasitic diseases.

Lafferty’s accomplishments have, in the words of Ward Medal Committee Chairman Charles Criscione of Texas A&M University, “brought parasites to the forefront of ecological research” and “extended the perception of parasites beyond the role of mere pathogens to major players in food-web dynamics and energy transport in ecosystems.” When Lafferty’s investigations were reported in Transect two years ago, he suggested the significance of parasites quite simply:

*If you drive by the marsh and look out the window, you see the egrets and all the other incredible bird life. But the biomass of the larval trematodes that live in the snails alone is greater than the biomass of all the birds living in the estuary. If you could see trematodes with binoculars, you wouldn’t bother looking at the birds because you’d be overwhelmed by the importance of the parasites in that system.*

Lafferty’s research in parasitology began at Carpinteria Salt Marsh (CSM) Reserve 20 years ago, and that NRS site continues to play a key role in his work. According to Lafferty, “There is no question that CSM is one of the most recognized field sites in the work of ecological parasitology.” He identified salt marshes as a useful model ecosystem for considering the role of diseases in an ecosystem, because such wetlands are subject to a wide range of man-made impacts and support a diverse community of trematode worm parasites.

The Henry Baldwin Ward Medal is presented by the American Society of Parasitologists in recognition of outstanding contributions to the field of parasitology. The medal is named for the society’s first president, who founded the Journal of Parasitology. This year is the 50th anniversary of the award. — SGR

For more information, check the following weblinks:
- UC Natural Reserve System Special Research Projects (April 2008), page 15: <http://nrs.ucop.edu/program_reports/Research_Projects.pdf>
Students learn how to see at reserve-based art course

A
nn often-mentioned benefit of the UC Natural Reserve System is that its sites provide settings where researchers from widely varied disciplines can cross paths, discover commonalities or new perspectives in their respective fields, and then work together to make unprecedented new discoveries. One such crossing of paths initially took place at UC Santa Barbara’s College of Creative Studies (CCS), but soon grew to incorporate NRS reserves, and the resulting partnership evolved to provide tremendous benefits to decades of students.

The story begins in the early 1990s, when two UCSB faculty members, paleobotanist Bruce Tiffney and fine artist Hank Pitcher, were discussing the key features shared by science and art. As Tiffney, who is now Dean of CCS, recalls: “One day Hank and I got into a friendly conversation, and we ended up agreeing that art and science are really about the same thing — they are about observation — and the distinction was in how you record those observations. In science, you try to squelch individuality, and you try to come out and make reports on what you have observed in the most dispassionate way possible; whereas in art, the eyes and mind of the individual observer are then applied to the interpretation. But it is all about seeing what is in front of you.”

For Pitcher, a soft-spoken painter whose work often portrays Southern California’s beach-and-surf community, true observation requires “slowing down, spending time, and really looking at things.” He provides a scientific example of what he means: “One of the things about geology, and fieldwork in the natural sciences, is that the scientists who keep the best notebooks and make the best drawings usually have the most profound insights. Drawing is a way of learning how to see. So geology students, if they’re able to see what’s going on, they’re able to draw it. And by drawing it, that helps them see it.”

Inspired by their conversation, the pair embarked on a teaching collaboration that resulted in a series of courses that combine art practice with natural history. Their first joint effort was a course on trees, their “botanical nature,” and how to represent that nature in a painting. While Tiffney helped the students perceive each plant from a scientific perspective, Pitcher helped them apprehend what they were seeing artistically. From there, they went on to develop a second course that challenged students to capture the flora of the UCSB campus in both illustrations and scientific descriptions. After twelve years of teaching this course, Pitcher and Tiffney have amassed a body of work that they hope to turn into a book on the subject.

Based on the success of these courses, the two professors began considering other ways to enable students to improve their observation skills. They were both aware of the Natural Reserve System and decided that two NRS reserves near UCSB might be ideal sites to help them meet this challenge. Over time they developed a landscape painting class that focused on the Coal Oil Point Natural Reserve, immediately adjacent to the Santa Barbara campus, and the Sedgwick Reserve, located in nearby Santa Ynez Valley.

“We both appreciated the fact that we have these incredible reserves here,” Pitcher explains, “and that it would be
During a plein air class at Sedgwick’s Anderson Overlook, professional artist Robin Gowen boldly attacks a large canvas, demonstrating an example of creative courage for the students. Photo by Bruce Tiffney

interesting to introduce the students to these areas. Most students have never done this. So we tried it. In the beginning, we took them up to the Sedgwick Reserve for a day, just to look at wildflowers. They responded quite strongly and wanted a deeper experience, so we took them up for a weekend, and the response was that they wanted even more.”

Tiffney recalls that Pitcher was really the inspiration for developing the new class: “Hank looked at the Sedgwick Reserve, and being a landscape painter, he decided that he’d really like to take students out in a course situation that is more similar to how he does his painting. His process is that he’ll go out for a couple of days and do nothing but paint — basically, an immersion experience. So we ended up designing a landscape painting course that has evolved into a three-weekend course.”

The class usually involves about 15 students, almost all of them undergraduates. The professors like to keep the class small enough that they can circulate throughout the group and offer feedback to individuals while the students are painting. They also recruit as many professional painters as possible, to paint alongside the students, to explain their techniques, and to share how they approach the problems involved in capturing a locale on canvas.

Landscape painting conducted on location is called *en plein air*, from the French phrase that means painting “in the open air.” The French Impressionists, beginning in the 1860s, were among the first to be fascinated by the process of representing a scene under constantly changing natural light, and painters since that time have developed their own techniques for solving the artistic challenges of working outdoors. At what point does one “freeze” the light? What is the true color palette of the landscape? Where do the shadows lie, and what do they reveal? The challenges are many, but so are the potential rewards. As one painter recently commented: “Anything you do live is better. Even if the image isn’t as pictorially accurate as something done from a photograph, it has more energy and vibrancy. The same thing is true in portraiture.”

Plein air painting also raises a series of logistical obstacles that must be overcome, ranging from easel maintenance, to selecting paints that won’t “seize up” too quickly, to dressing properly so one can remain comfortable while spending a day exposed to the elements. These issues are the primary focus of the class’s first Saturday at Coal Oil Point when the students gather at 9 a.m. at Pitcher’s studio near the reserve. They spend the first couple of hours getting their equipment into shape. Pitcher draws upon his studio’s resources to provide students with supplies or equipment they lack; Tiffney brings his toolbox and some splints to repair damaged French box easels or patch together metal easels.

The students then pack their gear and move over to Devereaux Slough on the Coal Oil Point Reserve. Once the painting begins, at perhaps 10:30, it doesn’t end until around 7 p.m., and during that time most students will complete two paintings. “It gets them used to painting for that long,” says Pitcher, “and because this reserve is closer to town, we can make sure they have all the right materials.” Tiffney doesn’t spend too much time talking to the students about natural history on this first day, but he does circulate among them as they paint, asking gently probing questions: “Are you seeing what you’re looking at? Do you understand why there are those funny-shaped triangular mountains on the ridge? Is the foliage you’re painting green actually green?”

At the end of the day, as the sun sinks low in the sky, Pitcher and Tiffney take their students out into a field for a hike and have them look up at the jagged range that looms over the city. “So, you see that peak there in the distance? Pitcher asks, indicating the highest point on the ridge. “Next week, you’re going to be the same distance from that peak, but you’ll be on the other side. How do you think it will be different?” His question introduces students to what they will see at Sedgwick and gives them a point of reference for understanding what they will see on the other side of the range where the elevation, temperature, and humidity are dramatically different.

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Students learn how to see
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Hank Pitcher’s plein air paintings are strongly composed and effective even when stripped of their vibrant colors and reproduced in black and white, as they appeared in the printed version of this Transect issue. The two works that appear on this page depict the NRS’s Coal Oil Point Reserve; the painting on the facing page (right) was derived from a scene at the NRS’s Sedgwick Reserve. All three are oil on canvas. Art and photos by Hank Pitcher

“I’m almost 60 years old,” Pitcher adds, “and working with the students has made me realize that life has evolved in a very peculiar way. Many students simply have no experience with Nature, so we end up with some kids who have literally never seen a sunrise before. They’ve grown up in cities, and this class is an incredible eye-opener for them.”

The initial goal is to have the students experience the low-angle light, shading, and sharp contrasts that appear when the sun is near the horizon. At times, what the students actually experience is how unpredictable Nature is and how quickly everything can change. “The changing light, particularly in the mornings, can be very amusing,” Tiffney explains. “There are morning fogs that turn up in summer, and you may wind up painting, for all intents and purposes, inside a Ping-Pong ball — you can’t see more than 100 feet away. Twenty minutes later, it all burns off and you have a totally different scene before you.”

Once at Sedgwick, the students are isolated from the outside world. Radios, headphones, iPods, cell phones, and other distractions are forbidden. Everything is focused on painting and on soaking up the environment. Thanks to a generous donor, the meals are catered, so students and staff don’t even have to worry about cooking.

“Here each student does four paintings a day,” Pitcher explains, “a sunrise, a morning light, an afternoon light, and a sunset. A lot of them are just learning where the sun comes up and where it goes down, that it doesn’t come up and go down in the same place, that the shadows change, all that kind of stuff. So generally the students

Total Immersion

On the first morning at Sedgwick, the cowbell starts ringing before sunrise. Hank Pitcher provides the alarm clock, and the students, some of whom may have spent a little too much time around the campfire the night before, groggily roll out of their sleeping bags and crawl out from under the tents or tarps they pitched the night before. As soon as the light begins to grow long, about 6 a.m., they begin painting. They will continue painting, with just a few short breaks, until the sun goes down.

“For most of the students, this is a totally new experience,” Tiffney observes. “Every once in a while, we get somebody who has done a little plein air. But more often, our students have not only not painted outdoors — in many cases, they’ve never camped outdoors.”
are painting all day long, and both Bruce and I are talking to them about their paintings as they’re working on them.”

The students are asked to simply, “Paint where you are.” Some focus on the trees; others focus on the sky or mountains. A few focus on human impacts evident in natural settings, painting a barn or other structure. The canvases of two such students stick in Tiffney’s mind as particularly well done: one depicted a propane gas tank and the grasses around it; the other, entitled “Three Graces,” was of an oak tree flanked by two port-o-potties.

When the daylight goes flat, about 10 or 10:30 each morning, the students stop painting and gather in Duke Sedgwick’s old studio for a critique (or “crit session”). During his time on the ranch, Sedgwick was a well-known local sculptor and painter, and his studio provides an excellent gathering place for the class. The students put their paintings up on the walls and discuss their work with the faculty — Pitcher, Tiffney, and the other professional painters — and with their fellow students.

Trees Are Not Camouflaged Lollipops

After lunch and a short siesta, Tiffney addresses some aspect of the reserve’s natural history. His first talk usually focuses on the trees that are found on the reserve. “My main point,” he explains, “is that many people think of trees as lollipops. You have a trunk and you put a sort of spherical crown on top of it, and that’s a tree. And, of course, all trees have brown trunks and green foliage, when, in fact, there are six or seven distinctive trees that are out there. I basically have them look at each of these trees individually. What is the color of the bark? What is the form of the bark? What is the color of the branching? What is the color of the foliage? How is the foliage borne on the tree? How does the foliage reflect colors from the sky?”

The students begin to look more carefully at the trees and observe that they are not just brown and green. Sometimes there’s a lot of red in the foliage. Reflections from the sky can create blues and purples. And each tree is unique, not just because of its separate species, but because of its individual life history. Some trees have broken branches or have grown lopsided; others stand extremely erect.

Tiffney explains to the students that they don’t have to faithfully record what’s out there, but if they truly want to capture the sense of a place, they must observe what constitutes that place. As he explains it: “I try to make it clear to them that you as an artist can alter a setting to fit your particular vision, but if this is going to be a painting that is somehow derived from a Southern California oak woodland, you can’t paint everything like palm trees with straight trunks and round crowns.”

**Chasing Shadows**

By 4 p.m., the students return to the field to paint. At this hour, the colors and shadows they see are completely different than they were in the morning. This visual shift prepares them for a key lesson. “When students first start to paint,” Pitcher explains, “and they realize that the shadows are moving, that the light is going up and down, they might say, ‘Gosh, where do I put the shadow?’ Well, that’s a fascinating thing. You see that the shadows are changing, you see that the colors are changing, the clouds appear and disappear, and it all gives you an opportunity to select where different things are going to be. And you make your selections based on whatever it is you want to talk about. Sometimes a shadow

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Students learn how to see
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will reveal the shape of a mountain. Sometimes a shadow will form a shape that a painter needs for the composition of a painting. So there's a great deal of information you get from being outside and experiencing something directly instead of working from a photograph.”

Beyond the philosophy of plein air, Pitcher and the other artists also provide specific tips on capturing a scene. The first step is deciding what you want to paint and getting the specifics down as quickly as possible. Sketch out where the shadows fall, their shape and length. Put in a few daubs of color to make sure they're right. Once you've stopped the instant in time, hold that image in your mind and focus on getting it onto the canvas. Some painters work on small canvases so they can finish them more quickly. Others return to the same site at the same time over multiple days to continue work on a single large painting. Another approach is to have multiple canvases underway simultaneously and simply switch from a morning-light scene to other versions as the day progresses.

Painting a moving target is a tough lesson for the students to learn. “Invariably, there are students, the first weekend out,” says Tiffney, “who are constantly chasing the shadows, repainting and repainting and repainting. They soon learn that this is the fast road to frustration — as well as muddy colors.”

Even after the sun sets, the students’ day is not over. They all bring their paintings back to the studio for dinner and another “crit session” that can last long into the night. Afterwards, most students don’t stay up too late, as they know the cowbell will be calling them again the next morning. By the time they leave on Sunday evening, the students are usually exhausted, but also elated by what they’ve learned and the progress they’ve made as painters.

On their second weekend at Sedgwick, the students return a bit quieter and go to bed a bit earlier. They focus on using what they learned in the first weekend to capture what they’re seeing now. The focus of Tiffney’s talk shifts to the geology of the area and the fact that a major fault runs right through the reserve. “The rounded hills in the foreground,” he tells them, “are made up of a fairly homogenous detrital material, the Paso Robles formation, and it makes beautiful, almost sensuous shapes. But if you look up beyond that, past the fault zone, you're into a major hunk of the Franciscan. That is the subduction zone that has been unearthed, and the rock colors completely change. There’s a lot less homogeneity to the rock, so the whole region is much more angular. Because it is a subduction zone, it’s rich in serpentine — high magnesium, nickel, iron. The vegetation has a totally different color. It’s much lighter and brighter than the vegetation in the foreground.”

The geology talk affects some students more than others. Tiffney recalls one student who took the lesson very seriously. “He had done a painting Friday evening where everything was gentle and rounded,” Tiffney recalls, “and he did the same painting Saturday afternoon after having heard this presentation where I discussed the kinds of pressures and temperatures that were involved in the subduction zone, and the uplift of the area, and the sense of the tortured Earth and moving planet. So, in the second version, all of his brushstrokes were much more energetic, and the whole thing in the background almost seethed and squirmed. As a landscape painting, he overdid it a bit, but he heard me about the landscape, and that was important.”
An NRS Tradition

For the nearly two decades that he was a professor at UC Santa Cruz, NRS founder Ken Norris oversaw his now-famous “Field Quarter” class that carried a busload of students to NRS reserves and other sites up and down the state. One of the final activities in the program he called a “niche watch,” where each student would spend a full day watching a single organism. Norris’s goal was to teach his students how to slow down and really see the landscape that surrounded them. He referred to this perceptual shift as “Mountain Time.”

Pitcher and Tiffney are following in Norris’s footsteps, helping students to see what is around them. The newbie artists are changed by their experience of Mountain Time. On the final morning of the class, each student mounts all of her or his paintings together — in the order they were painted — on boards hung from the fence enclosing Duke Sedgwick’s old tennis court. The students see immediately that their paintings have progressed dramatically. Part of the reason for this is mastery of technique, but mostly it’s the result of the students having had the total-immersion experience of really seeing what they’re looking at.

Pitcher explains: “What’s fascinating for the students, when they’re drawing and painting out at the reserves, is that they get my feedback as an artist. This has to do with some traditional pictorial concerns — composition, rendering, all that sort of stuff — and Bruce also talks to them in terms of what they’re looking at. A tree can be perfectly nice in a painting, and you can make it any shape you want to. But when he suggests this, he is also likely to observe: ‘Well, you have painted all those oak trees just the same, but there are really three different kinds out there. Did you notice that these oaks grow on the valley floors, those grow on the hills, and some of them have larger leaves, while others are slightly different colors…?’ So, the more they learn about the landscapes they’re in, the more interesting their paintings become, the more choices they have, the richer their work becomes.”

“The Sedgwick Reserve’s availability to campus is a huge asset,” Tiffney adds. “Its availability to us as part of the Natural Reserve System is critical. We know the people up there, and they know us. And it is a magnificent natural setting. If you squint your eyes and sort of eliminate an occasional scar on the far mountainside, you can imagine that you are somewhere much earlier in California history. The quality of the light there is generally excellent because of the dry air. The variability from morning to evening, particularly with the morning fogs, just throws a completely different set of problems at you throughout the day.” — JB
A FEW WORDS

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contribution of satellite technology, as well as to GPS navigation and other miraculous discoveries, that we give little thought to the extraordinary advances in science and in the understanding of the Earth that they imply. Compare the outcomes of two Category 4 hurricanes. In the deadliest weather disaster in United States history, a hurricane intensified over the Gulf of Mexico, then hit the Texas coast south of Galveston on September 8, 1900. Storm tides of up to 15 feet were largely responsible for the estimated death toll of 8,000. This hurricane came as a complete surprise.

By contrast, in 2005, early warning of Katrina two days before landfall, along with an estimate of its strength, kept the death toll to about 1,200, even as this storm inflicted catastrophic damage of some $75 billion, becoming the costliest hurricane ever to hit the United States. A 2008 National Research Council report posed this question: “Just what would the world be like without satellite remote-sensing?” — and provided the answer: “There would be no weather eyes in the sky, no global ability to monitor changes in atmospheric composition, in ecosystems and land use, in climate variability and change, in Earth’s surface and land-use changes, in ocean physical and biological processes, or in ice sheets.”

We are now in the early stages of development and deployment of Earth-based, networked-sensor systems and of electronic tags equipped with suites of sensors, which have begun to probe the many questions about Earth that cannot be answered from space. The lead story in this issue of Transect follows pioneering researchers at NRS reserves who have been at the forefront in these endeavors. One of them has even recruited ideally suited helpers — elephant seals and sea lions, athletic explorers of ocean depths in regions untouched by even the most intrepid of human explorers. These pinnipeds carry tags with sensors that harvest a wealth of oceanographic information, data transmitted to satellites when the animals surface.

— Alexander N. Glazer
Director, Natural Reserve System