THE NRS
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UNIVERSITY OF CALIFORNIA NATURAL RESERVE SYSTEM
OFFICE OF RESEARCH—DIVISION OF ACADEMIC AFFAIRS
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A FEW WORDS FROM THE DIRECTOR OF THE NRS

The direction and the magnitude of change [throughout the Earth's oceans] are virtually unpredictable at present because humans are changing the rules of the successional game on a continuous basis. Species go extinct, exotic species are introduced, the physicochemical environment changes continuously, the physical structure of the habitat is altered, and we exert chronic extractive pressure on most trophic levels. All this occurs at a timescale that is far shorter than the generation time of the largest organisms, which are typically strong interactors and often determine the diversity of entire communities.

— E. Sala and N. Knowlton
"Global Marine Biodiversity Trends"
Annual Review of Environment and Resources (2006) 31:93-122.

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LONE OAK AT HASTINGS NATURAL HISTORY RESERVATION IN CARMEL VALLEY. DNA ANALYSIS OF SUCH REPRESENTATIVES OF CLASSIC CALIFORNIAN *QUERCUS* SPECIES IS YIELDING INFORMATION THAT CAN INFORM FUTURE LAND-USE PLANNING AND PROTECT THE OAKS' GENETIC DIVERSITY. PHOTO BY DAVID J. GUBERNICK

IMPROVED STRATEGIES AND TECHNOLOGY FOR DESIGNING NATURAL RESERVES PROMISE GREATER SYSTEM BIODIVERSITY

California's ongoing population growth and rapid land transformation has long presented a challenge to groups attempting to protect habitats and species, both critical and common. It was the aim of the Natural Reserve System (NRS) founders, in the 1960s and 1970s, to assemble representative samples of all of California's ecosystems and thus enable research that investigates, along with teaching that communicates, what constitutes a balanced, healthy overall environment. A reserve system is built site by site, but unless an adequate selection strategy, broad in its perspective, is employed, too many reserves may be acquired largely on the basis of opportunity, creating a

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Designing Natural Reserves

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system insufficiently diverse. The NRS founders targeted specific ecosystems, applying the best scientific, academic, and administrative criteria of the day. Over the last thirty years, however, scientists have honed those criteria, gradually developing an even more rigorous approach to reserve siting, the process of determining where and why a piece of land should become a natural reserve.

Professor Frank Davis and researcher David Stoms, based at UC Santa Barbara's Biogeography Laboratory, are leaders in the emerging field of reserve design theory. "It's getting harder and harder to protect biodiversity in an ad hoc way," Davis observes. "A lot of the land where there are threats to biodiversity also has value for other things, whether it's agriculture or development. Conservation aimed at protecting species in those areas has gotten contentious and expensive. The challenge is to identify places where you can do conservation planning most cost-effectively, most efficiently, and with the least amount of conflict." With development pressures bearing down on all sides, stronger measures supported by cutting-edge technology are called for in the effort to protect and appropriately steward natural resources.

Contemporary reserve design theory combines a wide range of disciplines, from geography and conservation biology to land-use planning and economics. And, because almost all conservation decisions are made in the public arena and are often quite controversial, elements of sociology, political science, and the law also factor into the equation. For these reasons, scientists have developed sets of tools and algorithms for evaluating different conservation options. Organizations with straightforward missions, like the UC Natural Reserve System, now use these tools to guide land acquisition. In other, less focused situations — where groups with multiple interests and/or goals are involved — scientists serve as advisors and employ their tools to make all parties aware of possible conservation options. California's marine reserve science team (described in "Preserving Marine Ecosystems," page 4) is a perfect example of scientists being called upon to act as advisors in the public arena.

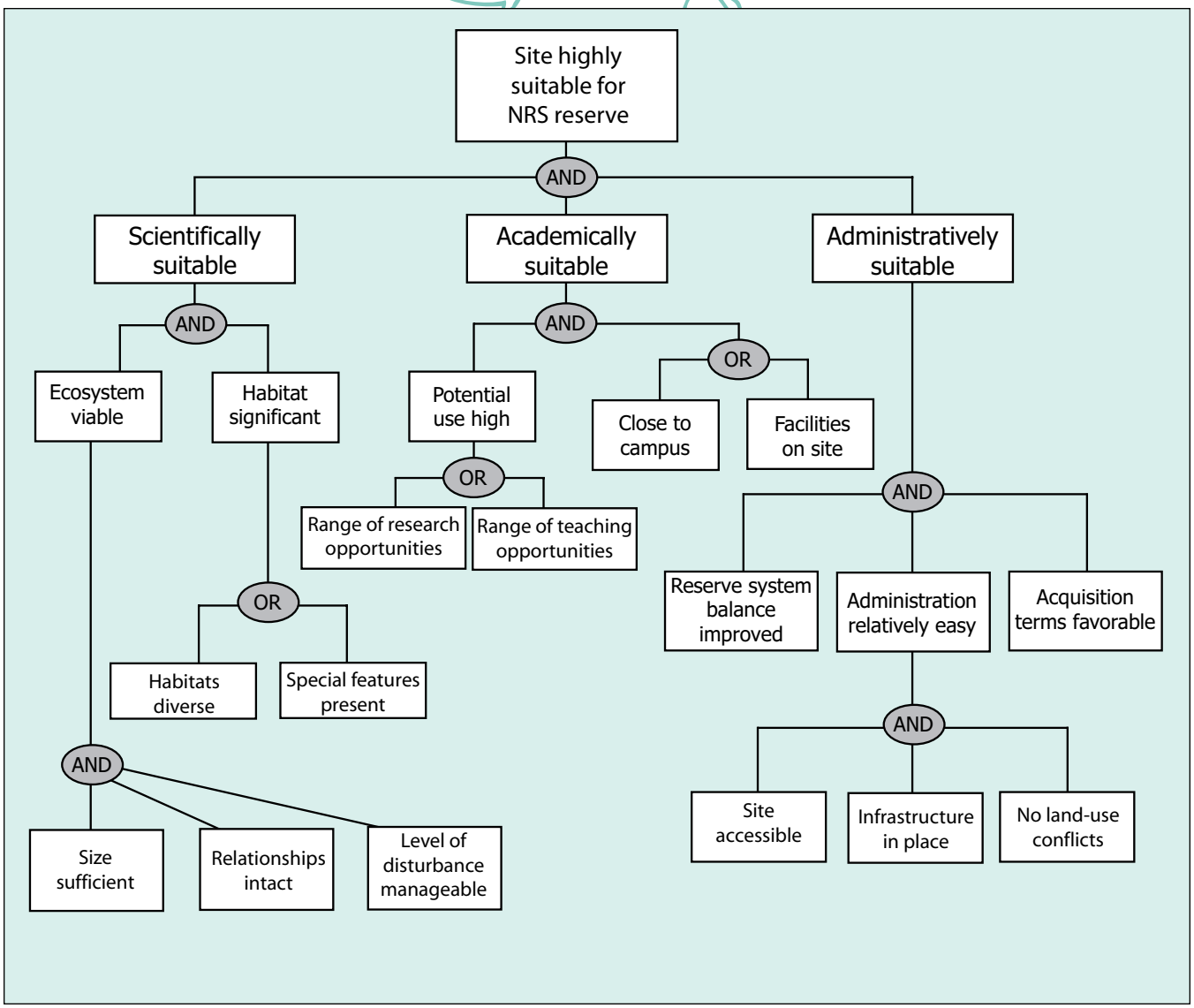
Determining What's Vulnerable

The first step in reserve design is to conduct a survey of existing reserves to determine their composition, species, ecosystem types, and size. Two questions to be answered are: what elements of biodiversity are already protected across the system? and what elements are in jeopardy? This process, called Gap Analysis, was originally accomplished by overlaying two maps, one showing existing reserves and the other showing the habitats for endangered species. Where the two overlapped, all was well. Where the two failed to overlap, scientists knew it was likely they would eventually have a new goal: to press for additional reserve land or at least corridors to protected land that could serve those species fortunate enough to be self-propelled.

Today more sophisticated Gap Analysis evaluations are carried out on computers, using data from geographic information systems (GIS), satellite-based remote sensors, following the extensive field research needed to locate the distribution of biodiversity elements. Gap Analysis not only identifies species and habitats unprotected by existing reserves, it often suggests possible ways to improve a reserve network's "coverage." As Davis explains: "You want sites that are both rich in what you're looking for and, also, complementary to what you already have. What's the minimum set of reserves that will cover all those elements? It sounds easy, but in practice it's a very large computational problem, so much of the work in that area has involved applying algorithms from operations research and decision science. It's almost become more of an engineering problem."

Davis and Stoms have been involved in a number of regional gap analysis projects. Beginning in 1990, for example, they worked with various federal, state, and local agencies on the California Gap Analysis Project. Stoms recalls that "our goal was to create statewide databases and then apply them to identify elements, communities, and vertebrate species at risk based upon patterns of land ownership and management." The California Gap Analysis Project was concluded in 1998; the resource databases it produced have proven valuable in focusing conservation efforts.

A number of modeling techniques have been developed for prioritizing land acquisitions. The simplest is a scoring approach. When the University of California Office of the President asked the UCSB Biogeography Laboratory to evaluate potential reserve sites for its tenth campus, UC Merced,[1] Stoms and Davis developed a list of NRS-specific concerns organized under the categories of scientific, academic, and administrative suitability. They then



A generic example of a decision-making "tree" that presents some of the criteria used to determine whether or not a site is worthy of reserve status. Based on figures developed by David Stoms

assigned values to potential sites in each category. This scoring approach identified highly suitable potential sites according to the criteria measured by the UC NRS guidelines. Candidate sites would then be evaluated with more specific information. "When assessing the suitability of potential reserve sites over a large region," Stoms explains, "you never have all the detailed information in maps that you would like. Therefore, you have to go with what you know to narrow the search space. As the search narrows, you generally find information about more of the criteria at higher spatial resolution. Ultimately, when you get down to a few parcels, you can go beyond the maps and fill in the missing data in the field."

Preserving Genetic Diversity

In addition to coverage — defined as protecting as many vulnerable habitats as possible — any modeling technique must take into account a number of other factors. For example, persistence — the probability that a current condition or set of circumstances will continue into the future at a particular level — has become a major question. As global warming not only continues, but accelerates, what is the likelihood that an endangered species, or the ecosystem that supports it, will soon disappear, anyway? Can the chances of that species disappearing be reduced by protecting its genetic biodiversity? Should individuals from the northern and southern extremes of that species' range be included in a reserve system in order to protect this biodiversity?

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Designing Natural Reserves

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UCLA Professor Victoria Sork teamed up recently with Frank Davis to consider genetic variation in oaks and the extent to which key areas of this habitat-defining genus were being protected, or not protected, in California.[2] "Diversity of habitat is important," explains Sork, "but how do we know we're not leaving some really important pieces of evolutionary history unprotected? If we're interested in protecting evolutionary hot spots, the only way we're going to do that is to look at the genetic history of populations."

Sork's genetic markers did in fact identify unprotected areas of high genetic diversity or genetic uniqueness for certain oak species. Her initial findings indicate that areas in the San Francisco Bay Area and at the southern extreme of the oaks' range might be critical to the future of these *Quercus* species. "Climate change makes this situation even more crucial," Sork notes. "If we want to preserve the full range of genetic variation, given that some genotypes adapted to warm climate are going to be in the south, we should make sure we try to preserve those areas. The southern populations have some unique variations that we don't see in the north. We may want to either preserve those populations or at least keep those acorns around to do restoration."

A Question of Dollars and Priorities

In the end, economics is often the deciding factor in reserve system design. Sites where the biodiversity is more threatened are often more expensive to protect. The tradeoff often comes down to spending less money to buy less threatened sites versus putting all the available money into more threatened areas, knowing that they will otherwise be lost. As Davis puts it: "Much of conservation planning focuses on reconciling what you know about the geography of threat with what you know about the geography of land markets."

In areas where people strongly contest the disposition of lands, the scientists' role is to use conservation planning tools to help all sides see what problems, opportunities, and different priorities might emerge, depending upon how matters are weighed. For example, one group might care more about endangered species or watershed protection, while another cares more about "smart growth"[3] and the preservation of agricultural lands. In California — in fact, wherever land planning is carried out — both these groups and many more may appear at the table, so a scientist may be called upon to fulfill a consulting role to help stakeholders understand the consequences of their choices.

Achieving an Integrated Approach

The last, crucial step in the reserve design process is incorporating conservation and design theory into a larger analysis of regional land-use dynamics to produce a more integrated approach to land planning. The Endangered Species Act (ESA) provided the catalyst for much of this effort. "The ESA really changed land planning in California," says Davis. "In areas with endangered species, you see much more integrated land planning that includes attention to biological concerns. This has led to a number of multispecies conservation programs across the state as part of the Natural Communities Conservation Planning (NCCP) process.[4] NCCP provides a legal and institutional framework within which local governments can allow development to proceed, even though there may be endangered species in the planning area, as long as they set aside enough habitat to conserve the species. Today twelve counties are doing large NCCPs that involve a lot of systematic conservation planning that tries to balance habitat conservation with development."

Though he admits that NCCP is an end-game measure — the species involved are, after all, endangered — Davis sees great value in the process. He says: "It's an important thing to do. Until recently, land planning has not considered ecosystem resources. We tended to put all of the natural resource management in the hands of one set of public agencies, and the land development process in a completely separate sphere, without any concern for natural resource protection. Today we see, more and more, that you can't separate the two."

Preserving Marine Ecosystems

California's terrestrial landscapes aren't the only areas under pressure. Its intertidal and near-shore marine environments are also being hit hard by human impacts, especially fishing and pollution. In response to these pressures, the California legislature passed the Marine Life Protection Act in 1999, directing the state Department of Fish and Game to design and manage a network or system of Marine Protected Areas (MPAs). After some trial and error, Fish and Game set up a multilevel process to design the system. Although the Fish and Game Commission makes the final decision, they act

on the recommendations of a statute-mandated "Blue Ribbon Task Force," which in turn takes into account proposals made by a number of stakeholder groups, such as fishermen, conservation groups, educators, and scientists.

Just as they have done with terrestrial systems, scientists are playing a key role in this process to design marine reserves. In fact, they often use the same tools, including software, to perform their gap analyses. Mark Carr, associate professor of ecology and evolutionary biology at UC Santa Cruz, serves on the Department of Fish and Game's science advisory team. "We didn't draw the boundaries of specific MPAs," he explains. "We established the guidelines for the system, and stakeholder groups proposed network packages based on our outline. Then we evaluated each proposal on how well it met the guidelines."

The scientists' first step was to examine the full range of biological communities along the entire central California coast, including their diversity, and to identify representative habitats that must be included across the whole system of MPAs. As Carr recounts: "Each plan had to include eight habitats: shallow sand, deep sand, shallow rocky reef, deep rocky reef, canyons, estuaries, kelp forests, and surf grass. We know that the biological communities on rocky reefs differ as a function of depth, so we came up with depth categories that had to be represented. This forced each plan to extend their MPAs offshore to encompass the diversity across that depth gradient."

Other key scientific guidelines are related to the size, spacing, and number of protected areas, as well as the levels of protection within each MPA. For optimal sizing, the panel looked at fish

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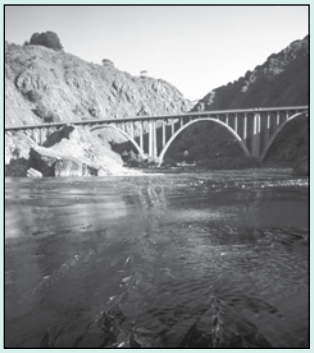
PISCO and the MLPA



The Landels-Hill Big Creek Reserve, on the Big Sur coast, is one of seven NRS reserves that is contiguous to a PISCO research site. Photo by Jeff Kennedy

It's not surprising that three members of the Marine Life Protection Act science team are also principal investigators in the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a major multi-university research project that focuses on understanding the nearshore ecosystems of the U.S. West Coast. In addition to Mark Carr from UC Santa Cruz, other PISCO investigators on the 18-member science team include Steven Gaines, of UC Santa Barbara, and Steve Palumbi, of Stanford University's Hopkins Marine Station.

Established in 1997 with core funding from The David and Lucile Packard Foundation and later from the Gordon and Betty Moore Foundation, PISCO integrates long-term monitoring of ecological and oceanographic processes at dozens of sites along a 1,200-mile coastline with experimental work in the lab and in the field. Their interdisciplinary research focuses on understanding three main issues:

(1) How currents, upwelling, and other physical and ecological processes affect the plants and animals of coastal marine ecosystems.
(2) How coastal ocean ecosystems respond to shifts in water temperature, currents, and other factors that may vary with global climate change.
(3) How ocean circulation affects the dispersal of marine organisms in their earliest larval stages.

It's also no coincidence that a number of PISCO research sites are located in waters off NRS reserves, including Bodega Marine Reserve (Sonoma County), Año Nuevo Island Reserve (San Mateo County), Landels-Hill Big Creek Reserve (Monterey County), Kenneth S. Norris Rancho Marino Reserve (San Luis Obispo County), Coal Oil Point Natural Reserve (Santa Barbara County), Santa Cruz Island Reserve (Santa Barbara County), and Scripps Coastal Reserve (San Diego County).

By protecting the adjoining terrestrial lands, these NRS reserves help guarantee that the underwater environments will remain relatively undisturbed. Because public access to the reserves is limited, PISCO investigators can rest assured that their collecting equipment and other scientific gear will not be interfered with and their work will not be interrupted. Additionally, each NRS site provides invaluable logistical support and facilities for PISCO field teams. —*JB*

Designing natural reserves

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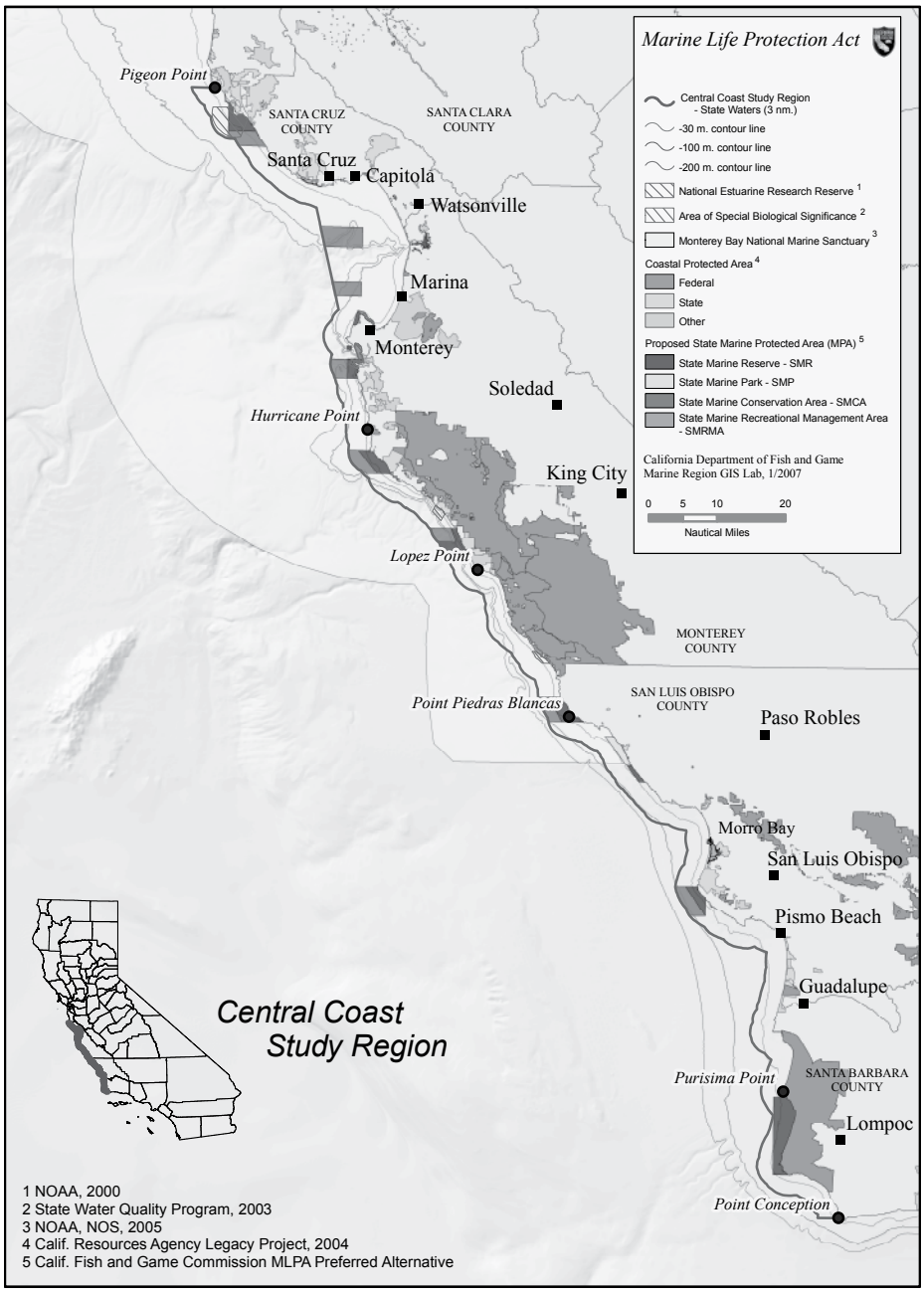
movement, then offered its recommendation for how large a reserve should be in order to encompass these movements throughout the fishes' lives.[5] Based upon this research, the panel determined that a marine reserve should stretch along the coast for a minimum of 5 to 10 kilometers (3 to 6 miles) and preferably 10 to 20 kilometers (6 to 10 miles).

To determine the optimal spacing between reserves, the group looked at the larval dispersal of different species. Unlike closed terrestrial ecosystems whose populations are replenished by their own young, marine ecosystems rely on the delivery of larvae from other areas for replenishment. After conducting a search of all the available literature on prevailing currents and larval duration (how long larvae remain in a water column[6]), the panel recommended a network of multiple smaller reserves spaced no more than 50 to 100 kilometers apart to maximize the transfer of larvae from one site to another.

Another factor that had to be considered was the taking of transient species, such as salmon and albacore, that move in and out of the MPAs. This was a critical issue for fishermen. After much discussion, the panel decided that depth was the key. Carr explains: "If you fish for a species like salmon at the surface in waters shallower than 50 meters, there's a very high likelihood that you'll catch other things, like rockfish. If you're in deeper waters — say, 150 meters — and you're fishing for salmon at 50 meters, there's a lower likelihood that you'll impact anything else in the system, so we decided to allow some fishing in the deeper MPAs."

At first, the progress of establishing system guidelines and evaluating MPA proposals was difficult and contentious, but now it seems to be picking up momentum. The Fish and Game Commission finalized the MPAs around the Channel Islands in 2003. In the fall of 2006, the commission selected a preferred alternative, along with two other alternatives to consider in the regu-



This map shows the locations of the CA Fish and Game (CFG) Commission's proposed state marine protected areas along the CA central coast, from just south of Pigeon Point to just north of Point Conception. Although the map is difficult to interpret in this grayscale reproduction, it nevertheless suggests the enormous complexity of resources and jurisdictions that must be considered in the process of designing marine reserves. Map courtesy of CA Department of Fish and Game, Marine Region

latory process, for California's central coast. Next they will look at the north and south coasts. Carr will remain involved in this process, especially as the panel's attention moves northward, but he also has plans to monitor the MPAs already established: "We're shifting the ongoing, long-term, large-scale monitoring we were already doing as part of PISCO [Partnership for Interdisciplinary Studies of Coastal Oceans] to new sites to collect baseline information on the new MPAs. To gauge their effectiveness, we'll need to sample both the protected areas and similar habitats outside of the protected areas over time."

More and more, reserve design, whether terrestrial or marine, is supported by technology and a broader perspective, yet complicated by controversy. People on all sides have strong vested interests. The likelihood is that these conflicts will become even more heated as time passes. The hope is that science can provide a framework for devising solutions. Frank Davis is philosophical:

We have to do this systematic work now because we've protected the stuff that's easiest to protect — it's remote, it's rugged, it's unproductive. But if we're really interested in protecting species and ecological communities, [then we must face the fact that] those most in jeopardy are often located where the interests are most in conflict. Every local land planning process in California is very contentious. We hope to bring more systematic information to bear and to help people understand all of the different dimensions of the conservation problem. Science is just part of the process. It can contribute, but it can't make the ultimate decision. That's a much more complex social process.

— JB

Endnotes

[1] Stoms, D. M., J. M. McDonald, and F. W. Davis. 2000. *Knowledge-based site suitability assessment for new NRS reserves for the proposed UC Merced campus.* Santa Barbara, University of California. PDF available online at: **<http://www.biogeog.ucsb.edu/pubs/Technical%20Reports/Technical%20Reports.htm>**.

[2] Sork, V. L., F. W. Davis, and D. Grivet. 2006. *Incorporating Genetic Information into Conservation Planning for California Valley Oak.* Presented at the Sixth Symposium of Oak Woodlands, Sonoma, CA, Oct. 9-11, 2006.

[3] *"Smart growth," a philosophy underlying certain policies governing urban land-use planning and transportation, seeks to benefit communities while preserving the natural environment. Smart-growth proponents advocate: the creation of communities, each of which has a unique sense of identity as a unified body of individuals with common interests living in a particular place; the preservation and enhancement of natural and cultural resources; equitable distribution of both the costs and the benefits of development; expansion of the range of transportation, employment, and housing options; choice of long-range, regional considerations of sustainability over short-term focus; and the promotion of both public health and healthy communities.*

[4] *The Natural Communities Conservation Planning (NCCP) program is a cooperative effort run by the California Department of Fish and Game to conserve natural communities at the ecosystem scale while accommodating compatible land use. The program, which began in 1991 under the state's Natural Community Conservation Planning Act, is broader in its orientation and objectives than the state or federal endangered species acts that protect individual species. Its objective is to anticipate and prevent the controversies and gridlock caused by species' listings by focusing all key interest groups (government agencies, environmental groups, developers) on the long-term stability of wildlife and plant communities.*

[5] *The effort that must be dedicated to collecting information before any analysis can commence or recommendations can be advanced is staggering. Information-gathering is thankless, neverending work, involving both field research and literature searches. And still the amount of data available can be limited. Science panels are criticized at times for not having sufficient data, but they do the best they can with what they have. One of the main reasons the NRS was created was to enable just such efforts, thereby benefiting land-use planning and management in an arena that extends well beyond the 130,000 acres that presently comprise the UC reserve system.*

[6] *A water column is a vertical section of the sea. By moving up and down in a water column, larvae are able to catch different currents. Currently, the big question is: to what extent are larvae able to choose which currents they enter and where they end up? In the past, scientists assumed that larvae were mostly just floating, that chance alone determined their ultimate landing places. Now some scientists argue that larvae have more control over their own destinies than was previously thought.*

UC Natural Reserve System

At the conclusion of 2006, the NRS had 35 sites across the state of California, encompassing about 130,000 acres, roughly 22 percent of which the University of California holds title to; the rest is owned by various federal and state agencies or private natural resource organizations, such as The Nature Conservancy, and managed by UC under a multiplicity of use agreements. The day-to-day administration of individual reserves is assigned to eight of the ten UC campuses.

NRS Reserves listed by Administering UC Campus

UC Berkeley

1. Angelo Coast Range Reserve*
3. Jenny Pygmy Forest Reserve*
5. Sagehen Creek Field Station
6. Chickering American River Reserve
16. Hastings Natural History Reservation

UC Davis

2. Eagle Lake Field Station
4. Donald & Sylvia McLaughlin Reserve
7. Quail Ridge Reserve
8. Stebbins Cold Canyon Reserve
9. Bodega Marine Reserve
10. Jepson Prairie Reserve*

UC Irvine

25. Burns Piñon Ridge Reserve
29. San Joaquin Freshwater Marsh Reserve

UC Los Angeles

23. Stunt Ranch Santa Monica Mountains Reserve

UC Riverside

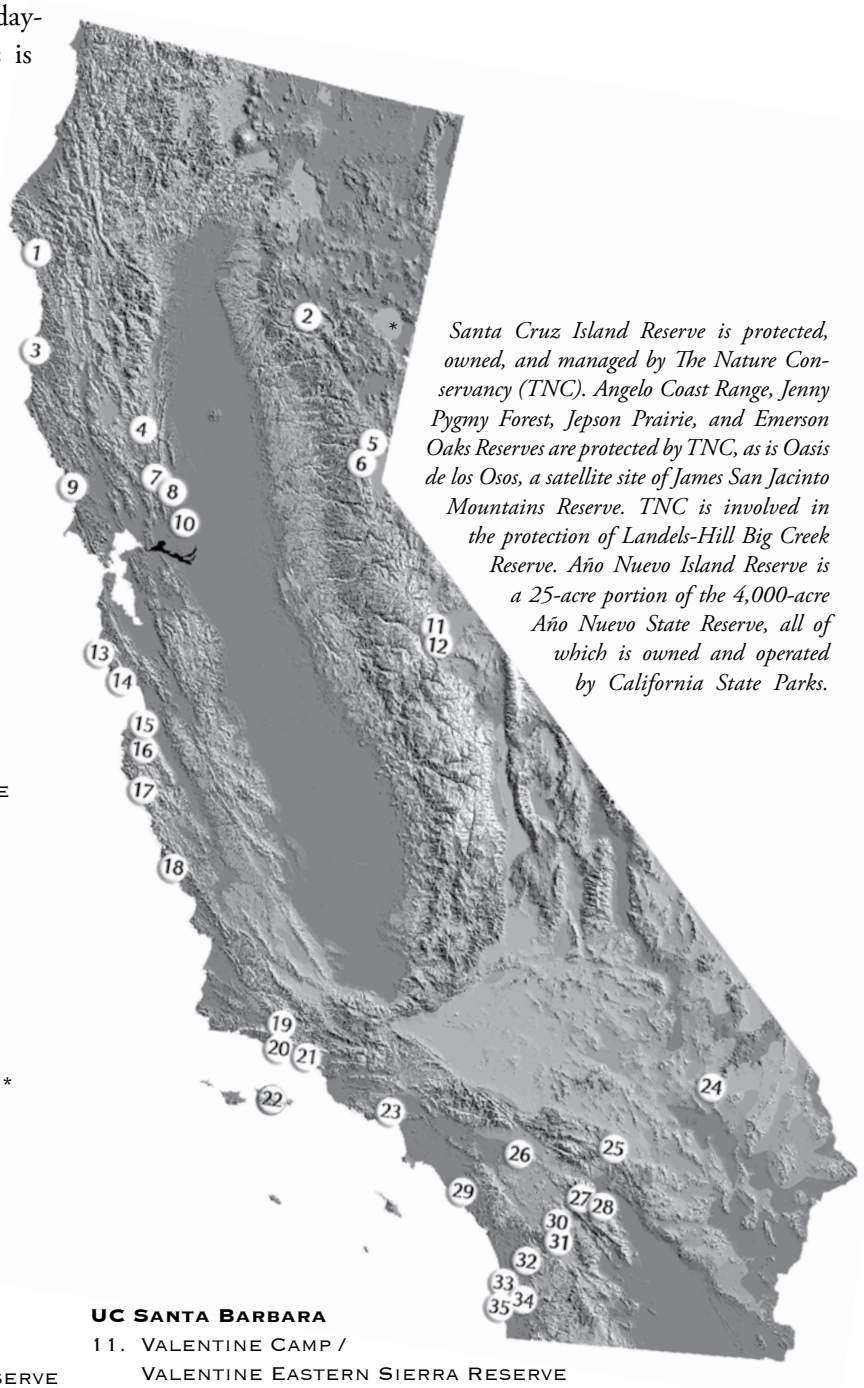
24. Sweeney Granite Mountains Desert Research Center
26. Box Springs Reserve
27. James San Jacinto Mountains Reserve*
28. Boyd Deep Canyon Desert Research Center
30. Motte Rimrock Reserve
31. Emerson Oaks Reserve*

UC San Diego

32. Dawson Los Monos Canyon Reserve
33. Scripps Coastal Reserve
34. Elliott Chaparral Reserve
35. Kendall-Frost Mission Bay Marsh Reserve

UC Santa Cruz

13. Año Nuevo Island Reserve*
14. Younger Lagoon Reserve
15. Fort Ord Natural Reserve
17. Landels-Hill Big Creek Reserve*



Santa Cruz Island Reserve is protected, owned, and managed by The Nature Conservancy (TNC). Angelo Coast Range, Jenny Pygmy Forest, Jepson Prairie, and Emerson Oaks Reserves are protected by TNC, as is Oasis de los Osos, a satellite site of James San Jacinto Mountains Reserve. TNC is involved in the protection of Landels-Hill Big Creek Reserve. Año Nuevo Island Reserve is a 25-acre portion of the 4,000-acre Año Nuevo State Reserve, all of which is owned and operated by California State Parks.

UC Santa Barbara

11. Valentine Camp / Valentine Eastern Sierra Reserve
12. Sierra Nevada Aquatic Research Laboratory / Valentine Eastern Sierra Reserve
18. Kenneth S. Norris Rancho Marino Reserve
19. Sedgwick Reserve
20. Coal Oil Point Natural Reserve
21. Carpinteria Salt Marsh Reserve
22. Santa Cruz Island Reserve*

The NRS Role in California's Protected Environments

How do the 130,000+ acres managed by the UC Natural Reserve System figure into the state's network of protected lands? Although the acreage represented by NRS reserves is relatively small in the context of the entire state's 101,571,840 acres, UC Santa Barbara Professor Frank Davis feels the reserve system nevertheless plays an important role:

> *The NRS is interesting because its holdings are in some ways complementary to the holdings of the major land management agencies like the National Park Service and the U.S. Forest Service. Those agencies tend to protect higher elevation montane environments and species, whereas many NRS sites happen to be located on the valley floor or in the foothills. So, in that sense, the NRS is a very important part of the network, because it tends to better represent some of those environments that are often the hardest lands to preserve since they have a lot of other uses like housing, agriculture, and development.*

According to UC Santa Cruz Associate Professor Mark Carr, who serves on the California Department of Fish and Game's scientific advisory panel to help design Marine Protected Areas (MPAs), the NRS also plays a key role in California's offshore marine reserve system. Though most people think of terrestrial and marine environments as separate entities, there's a huge interaction between what happens on land and what happens directly offshore in the ocean. The formation of extensive biological "dead zones" in coastal waters as a result of the outflow of nutrients released from agricultural practices is a dramatic example of such land-sea interactions.

Mark Carr worked with Frank Davis and David Stoms to consider land/sea interactions and how they should be taken into account when designing marine protected areas.* "It's important that you think about what's happening on land when siting MPAs," Carr notes. "One of the strongest interactions is through watersheds, so you have to think about the need to protect watersheds if they're impinging on marine reserves. On the other hand, you don't want to place an MPA in the path of a watershed that's been highly perturbed."

Carr isn't surprised that two of the state's larger MPAs on the central coast are located adjacent to NRS coastal reserves: the Landels-Hill Big Creek Reserve in Monterey County and the Kenneth S. Norris Rancho Marino Reserve in San Luis Obispo County. "Big Creek, especially," he says, "is a perfect example of a watershed that is relatively pristine, and the underwater environment off of Norris Rancho Marino is very rich."

NRS reserves also provide another crucial element that Carr calls "eyes on the water." Enforcing the boundaries of and restrictions in many of the new MPAs will require the use of ships and planes; however, the resident managers, stewards, and researchers at NRS sites will provide trained observers for adjacent marine reserves. "People like Kurt Merg (resident manager at Big Creek) and Don Canestro (resident manager at Norris Rancho Marino) are going to be really important," notes Carr. "Don has been involved throughout this process, serving on the education and research stakeholder group. His work has been invaluable." —*JB*

* Stoms, D. M., F. W. Davis, S. J. Andelman, M. H. Carr, S. D. Gaines, B. S. Halpern, R. Hoenicke, S. G. Leibowitz, A. Leydecker, E. MP Madin, H. Tallis, and R. R. Warner. 2005. "Integrated coastal reserve planning: making the land-sea connection." *Frontiers in Ecology and the Environment* 3: 429-436.

Dedication ceremony for Sagehen Experimental Forest links UC reserve system with nationwide network

Research networks have proven critical as scientists struggle to understand regional, continental, and even global-scale environmental issues. The National Area Deposition Program (NADP), a nationwide network of precipitation-monitoring sites begun in 1978, was essential in identifying the impacts and causes of acid rain. The Long Term Ecological Research (LTER) Network, established in 1980, has deepened understanding of diverse ecosystems across the country. Today terrestrial scientists are deep into planning the National Ecological Observatory Network (NEON), while marine scientists have already developed a parallel Ocean Research Interactive Observatory Network (ORION).

The NRS is ahead of the curve. From the reserve system's founding in 1965, Ken Norris and his colleagues were adamant that the disappearance of research and teaching sites was a statewide issue that required a coordinated statewide solution. Single, isolated reserves would be too subject to local development pressures and unable to provide sufficient coverage of the state's ecological diversity.

The value of reserve networks was a primary theme at the Sagehen Creek Field Station on June 24, 2006, when officials from the U.S. Forest Service (USFS), the USFS's Pacific Southwest Research Laboratory, UC Berkeley, and the UC Natural Reserve System gathered to dedicate the Sagehen Experimental Forest. The ceremony marked the linking of the NRS's 35-reserve statewide system, with the Forest Service's national system of 84 experimental forests. Ann Bartuska, USFS Deputy Chief for Research and Development, stressed the importance of this university/agency link-up. "Reinforcing the partnership between UC and the Forest Service," she noted, "is important because both the scientific community and the management community are turning to networks as a foundation for understanding how systems work."

Bernie Weingardt, Regional Forester for the USFS's Pacific Southwest Region, feels that the 7,900-acre Sagehen Experimental Forest offers a wide range of research opportunities that will have a direct impact on forest management. He said: "We're facing a host of critical issues — global climate change, invasive species, fuels buildup, water quality and quantity, sensitive species and their habitats. And, quite frankly, we have to have the best science available for us to begin to address these issues."

Steve Eubanks, Forest Supervisor for the Tahoe National Forest (which includes the Sagehen Basin), worked with researchers at the H. J. Andrews Experimental Forest while at the Willamette National Forest in Oregon. "The [experimental] forests become magnets for research, places where our managers can come out and work with researchers," he explained. "So they don't just read about experimental results three or four years down the road, but are actually on the ground, talking with the researchers firsthand, which also gives them an opportunity to influence what research occurs."

Main participants at the Sagehen Experimental Forest dedication: (left to right) Laurie Goldman, Director of Planning and Research, UC Berkeley; Bob Price, Assistant Vice Chancellor for Research, UC Berkeley; Steve Eubanks, Tahoe National Forest Supervisor; Jim Kirchner, faculty manager, Sagehen Creek Field Station, UC Berkeley; Ann Bartuska, USFS Deputy Chief for Research and Development; Jeff Brown, resident manager, UC NRS's Sagehen Creek Field Station; Jim Sedell, Director, Pacific Range and Experiment Station; Bernie Weingardt, Regional Forester for the USFS's Pacific Southwest Region. Photo by Jerry Booth

Under the guidance of faculty Manager Jim Kirchner, station Manager Jeff Brown, and Assistant Manager, Faerthen Felix, Sagehen Creek Field Station has become the focus for a growing number of UC-based research projects. For example, John Battles and Scott Stephens, from UC Berkeley's College of Natural Resources, are conducting a major, multi-year investigation into the impacts and effectiveness of the Strategically Placed Area Treatments (SPLATS) used by the Forest Service to reduce the chance of high intensity/high severity fires.

Jim Kirchner, Professor, Earth and Planetary Science at UC Berkeley and faculty manager of the Sagehen Creek Field Station, is a long-time researcher in the region. Photo by Jerry Booth

Another example is a multidisciplinary research group, led by Kirchner and his colleague at UC Berkeley Inez Fung, which has just started the $1.6-million Keck Hydro Watch Center to investigate each phase of the water cycle and track the flow of water through watersheds. A major focus of the project will be to compare water movement in the snow-dominated Sagehen watershed to the rain-dominated system at another UC NRS site, the Angelo Coast Range Reserve, located in Mendocino County.

Researchers are attracted to Sagehen for a number of reasons. First, the station's long-term data sets, compiled over the past 55 years, are unmatched in the Sierras. They include comprehensive animal and plant species lists, stream flow and chemistry data, weather (precipitation, snow depth, temperatures, etc.), soil maps and soil-pit data, and data from the National Atmospheric Deposition Program, to name just a few. The basin has been the research locale for over 70 doctoral dissertations and master's theses, as well as hundreds of published papers.

Building upon this, Brown and Felix have overseen the installation of a wide range of new sensors and communication systems. As Brown explains: "Our data collection infrastructure within Sagehen Experimental Forest and the balance of the Central Sierra Field Research Stations (which includes the Chickering American River Reserve, the Onion Creek Experimental Watershed, the Central Sierra Snow Laboratory, and North Fork Association Lands) is experiencing rapid growth in both the numbers and the types of deployed sensor networks and the archiving of data collected."

The SPLATS Project has also produced two major data sets that will be invaluable to all researchers: in-depth vegetation and fire fuel surveys at 525 marked plots throughout the watershed, along with 1-meter-resolution, laser technology-based LIDAR maps that provide both bare ground and vegetation-height data processed to work in ARC GIS 9.0 software.

These factors, as well as Sagehen Creek Field Station's position as a nexus for both statewide and national reserve systems, insures this NRS reserve's place as a major research center that will play a key role in shaping the country's environmental future. —*JB*

The new Sagehen Experimental Forest offers another 7,900 acres of research opportunities. Photo by Jerry Booth

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Wide range of UC classes take to the wild — with meaningful results

Whenever UC Santa Barbara archaeology students get their first field experience at the Santa Cruz Island Reserve, whenever art students from UC Santa Cruz travel to Big Sur and spend the day learning landscape photography at the Landels-Hill Big Creek Reserve, whenever UC San Diego marine biology students study intertidal zones on the pier pilings at the Scripps Coastal Reserve, then the UC Natural Reserve System is fulfilling the key role that it plays in the University's core educational mission.

A recent systemwide tabulation revealed that, during 2003-04 (the most recent academic year for which relatively complete data were available), 131 UC courses used NRS reserves. This total is impressive, and so is the variety of classes it represents. Biology- and ecology-related subjects dominate, with more than 70 courses. But the physical sciences, such as astronomy and geology, and environmental management were also well represented, each with about 20 courses. And a growing number of social sciences and art courses are also discovering the value of reserve visits. As UC Davis English Professor David Robertson notes: "The natural reserves, without exception, have really intriguing human interests. These are places where we can take students who are interested in nature, in the wild, and show them that what they see on the ground is often fundamentally, crucially determined by what humans have been doing there."

UCI's Peter Bowler (right) with his *Limnology and Freshwater Biology Lab* (Biology 179L) class at San Joaquin Freshwater Marsh Reserve, displaying an osprey nest. Photo courtesy of Peter Bowler

The effectiveness of these courses is often due to the intensity of the field experience. UCLA Professor Hartmut Walter takes his *Field Analysis in Biogeography* class to the Santa Cruz Island Reserve, off the coast of Santa Barbara, every year. The students' days are long: visiting sites and collecting data in the field during the day, analyzing the data on their computers over dinner, making presentations that often last long into the night. "The students learn almost as much from themselves as they do from me," Walter observes. "They watch each other's presentations. They compare what they are doing to what others have done. They learn from their mistakes and have no hesitation asking questions and criticizing each other. This gives them confidence."

Nowadays, reserve visits are especially important, since a majority of UC students come from urban and suburban environments. At UC Riverside, for example, John Rotenberry has been teaching *Evolutionary Ecology of Terrestrial Vertebrates* since 1989. The course takes students to four reserves: Motte Rimrock Reserve, Boyd Deep Canyon Desert Research Center, James San Jacinto Mountains Reserve, and Sweeney Granite Mountains Desert Research Center. As Rotenberry notes: "It's clear that many of the students aren't acquainted with the natural world. The Granite Mountains trip, especially, makes them nervous. It's a three-and-a-half-hour drive, but it's worth it, because it introduces them to a whole new world filled with toads, snakes, lizards, and birds. And most of them grow to like it. It's funny how a couple of good snakes can make a field trip!"

Faculty members also receive great satisfaction from working in the field with small groups of motivated students. Kaustuv Roy, who teaches a *Marine Invertebrate Ecology* laboratory at UC San Diego, makes extensive use of the Scripps Coastal Reserve near campus. "It's a great learning environment," Roy observes. "I know each of the 20 to 25 students by name. They feel comfortable knocking on my door when they have questions. Small classes like this lend themselves to real teaching."

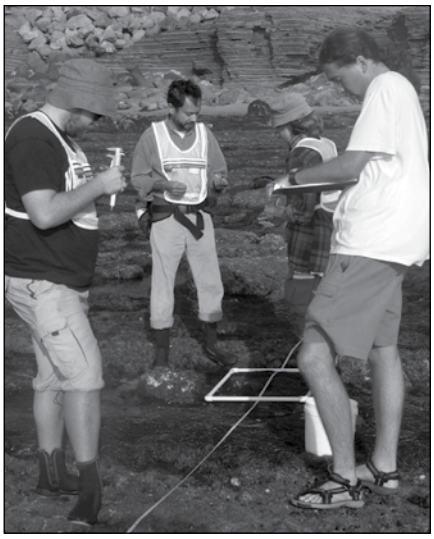
Classes in the field are also valuable because they can give added meaning to facts and theories learned in the lecture hall. UC Santa Cruz Professor Don Croll teaches *Ecological Field Methods*, a popular course that uses three reserves: Younger Lagoon Reserve, Año Nuevo Reserve, and Landels-Hill Big Creek Reserve. Though the class focuses on field research techniques, it brings alive other subjects as well. "Almost all of the students have had statistics before," Croll notes, "but they don't remember it. Now they have a motivation to learn. By the end of the quarter, I'll hear them comparing the value of different statistical methods, and it feels good because you know they didn't know any of this stuff coming into class."

A field course is often a student's first opportunity to work in the real world. For upper-division geology students, a field course can represent a major career advance. UC Riverside Professor Michael McKibben takes his *Introductory Petrology* class to the Sweeney Granite Mountains Desert Research Center in the Eastern Mojave Desert. He says: "The students have spent a lot of time reading and in labs, studying hand specimens of rocks and minerals. But on these trips, we throw them out on a mountain range and ask them to figure out what all the rock types are, and what all the minerals are, and how this mountain got here. That's a big step for them. It's a step in spatial scale, and in integrating all this lab and book work that they've done, and applying it in the field."

And if a few hours or a few days spent at an NRS reserve can affect students so deeply, is it possible a few weekends spent on-site could stay with them throughout their lives? The answer is clearly yes. UC Santa Cruz's *Natural History Field Quarter* has been introducing students to reserves throughout the state since 1975. Generations of students, a number of whom have gone on to careers in environmental sciences and land management, look back upon the experience as a seminal event in their lives. As field quarter instructor Professor Steve Gleissman observes: "People come out really motivated in lots of different ways ... the course changes the way they treat nature. It's wonderful to see. It's one of those transformational experiences that really works."

UC Riverside campus NRS director Professor John Rotenberry confirms Gleissman's observation and emphasizes the importance of fieldwork for all students. "We aren't going to turn most of them into ecologists," he admits, "but they are going to vote someday, and we want them to have an appreciation of the natural world, so they'll understand the implications of the decisions they're making." —*JB*

Editor's Note: The tabulation and analysis that provided information for this article are available in an NRS systemwide publication, UC Courses Hosted by UC Natural Reserves. *Single printed copies are available upon request from: Editor, UC Natural Reserve System, 1111 Franklin Street, Oakland, CA 94607-5200; phone: 510-987-0159; email: susan.rumsey@ucop.edu. A PDF of the document can be viewed at: <**http://nrs.ucop.edu/UC_Courses_Brochure.pdf**>. If you wish to bring a class to an NRS reserve, you can explore the system's 35 sites through the systemwide website at <**http://nrs.ucop.edu**>, then apply online by filling out a Reserve Use Application: <**http://www.ucnrs.org/rams.html**>.*



UCSD's Kaustuv Roy (center) with students, collecting intertidal zone data. Photo by Jerry Booth

UCSC's Don Croll (left) demonstrates ecological field methods to students in his Biological Sciences 141 class at Younger Lagoon Reserve. Photo courtesy of Don Croll

New director at Sedgwick Reserve bears watching

Kate McCurdy, Sedgwick Reserve's new director, likes to get her hands dirty. At UC Davis, the Santa Barbara native preferred the raptor center to university classrooms. At Cal Poly San Luis Obispo, she spent most of her time working on the university's farm. Best of all was her internship at Glacier National Park, working with grizzly bear researchers. McCurdy recalls, "We hiked the backcountry for a week at a time, collecting bear scat. That's when I realized how interesting bears were."

McCurdy took a second internship with the National Park Service's bear program at Yosemite. The program's goal was to reduce the damage bears were causing in the park. "I thought I'd be there for the fall," McCurdy explains, "but ended up staying for eleven years and heading the program. Working with bears is a great challenge because they're smarter than many park visitors."

Wanting to go to graduate school, McCurdy returned to Santa Barbara, but didn't leave the national parks. One position had her tracking coyotes and mountain lions in the Santa Monica Mountains; another sent her out to the Channel Islands to work on the Island Fox Recovery Program.

Enrolled in California State University at Humboldt's program in natural resource management, McCurdy focused on the human dimensions of wildlife management. Her recently completed master's thesis took her back to the Yosemite High Country where she studied bear/backpacker interactions.

How does this bear-centric background prepare McCurdy for her new position? "The bears at Yosemite forced everyone to work together to achieve our goals. It was a matter of finding the common ground and what needs to be accomplished. At Sedgwick, there will be conflicting views, but with a ranch that size [nearly 5,900 acres], there's room for everybody."

At Sedgwick, McCurdy is anxious to get her hands dirty again, "getting the infrastructure ready for expanded use. The master plan is excellent, and I want to move it forward." —*JB*

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Kate McCurdy: (Above) in bear country at the Grand Canyon of the Tuolumne River, Yosemite, CA. Photo courtesy of Kate McCurdy (Right) as Sedgwick Reserve's new resident director. Photo by Jerry Booth

NRS announces 2006-07 grad student grant winners

The UC Natural Reserve System has announced the 15 winners of the 2006-07 Mildred E. Mathias Graduate Student Research Grants. The grants are awarded each year to promote research at NRS sites, while providing UC graduate students with crucial experience in designing and managing field research projects.

This year's winners come from six UC campuses — Berkeley, Davis, Los Angeles, Riverside, Santa Barbara, and Santa Cruz — and plan to work at 11 different reserves. Their research topics range from anthropology (human migration at Santa Cruz Island Reserve), to evolutionary biology (development of anti-predator defenses in frogs at the Stunt Ranch Santa Monica Mountains Reserve), to conservation (preserving California tiger salamander habitat at Jepson Prairie Reserve).

This prestigious grant program was established in 1988 and named in honor of Mildred Mathias, a legendary UCLA professor and NRS founder. Over the last 18 years, faculty judges have awarded more than 300 grants and given out more than $450,000. In addition to the financial support from the grants, all Mathias winners are invited to a three-day Mathias Symposium, where they have the opportunity to meet their colleagues and present the results of their research. The next symposium will be held in early 2008.

More information about the Mathias Graduate Student Research Grant Program is available on the NRS systemwide website at: <**http://nrs.ucop.edu/Mathias-Grant.htm**>. A complete roster of 2006-07 winners is presented below and also at: <**http://nrs.ucop.edu/Mathias-06.htm**>. Highlights and PDFs of the programs from the 2004 and 2006 Mathias Symposia can be viewed by going to: <**http://nrs.ucop.edu/Mathias-Symposium.htm**>. —*JB*

2006-07 Recipients of the Mildred E. Mathias Graduate Student Research Grants

(with student names, department affiliations, research project titles, and NRS reserves hosting the investigations)

UC Berkeley

Matthew MacManes (Integrative Biology), *Interactions between Infectious Disease, Genetic Diversity, and Mating Systems*, at Boyd Deep Canyon Desert Research Center

Jennifer Skene (Integrative Biology), *Ecology, Distribution, and Morphology of the Intertidal Alga* Pelvetiopsis limitata, at Bodega Marine Reserve

Adam B. Smith (Energy & Resources Group), *Developing a Mechanistic Understanding of the Species-Area Relationship from Serpentine Habitats*, at McLaughlin Natural Reserve

UC Davis

William W. Dowd (Wildlife, Fish, & Conservation Biology), *Limits to Ecophysiological Plasticity in Dynamic Environments? Integrated Physiological and Behavioral Responses to Salinity Challenges in Estuarine Sharks*, at Bodega Marine Reserve

Barbara M. Going (Environmental Science & Policy), *Effects of Climate, Soil Type, and Competition on the Success of Serpentine Endemics*, at Landels-Hill Big Creek Reserve, McLaughlin Natural Reserve, and Sedgwick Reserve

Christopher Searcy (Evolution & Ecology), *Conservation of Terrestrial Habitat for California Tiger Salamanders*, at Jepson Prairie Reserve

Hilary M. Swarts (Wildlife, Fish, & Conservation Biology), *Mechanism Behind Diurnal Activity Changes of Santa Cruz Island Foxes*, at Santa Cruz Island Reserve

UC Los Angeles

Brittany Enzmann (Ecology & Evolutionary Biology), *Resource Investment, Storage-Protein Gene Expression, and Phenotypic Plasticity in* Pogonomyrmex *Harvester Ants that Vary in Colony-Founding Strategy*, at Motte Rimrock Reserve

Katherine Pease (Ecology & Evolutionary Biology), *Evolution of Anti-predator Defenses in a Native Frog in Response to an Invasive Crayfish*, at Stunt Ranch Santa Monica Mountains Reserve

UC Riverside

Lori Hargrove (Biology), *Avian Response to Ecological Gradients*, at Boyd Deep Canyon Desert Research Center

UC Santa Barbara

Kristina Gill (Anthropology), *Relative Importance of Plant Resources through Time on Santa Cruz Island*, at Santa Cruz Island Reserve

Amy Gusick (Anthropology), *Early Maritime Hunter-Gatherer Occupation and the Initial Human Migration into the New World*, at Santa Cruz Island Reserve

UC Santa Cruz

Holly Alpert (Environmental Studies), *Snow Depth and Microhabitat Effects on* Pinus jeffreyi *Establishment at a Conifer Forest-Sagebrush Steppe Ecotone*, at Valentine Eastern Sierra Reserve: SNARL

Kris Hulvey (Environmental Studies), *Effect of Native Forb Abundance on Invasion Resistance*, at McLaughlin Natural Reserve

Michael C. Vasey (Environmental Studies), *What Is the Relationship between Coastal Fog and Maritime Chaparral?* at Fort Ord Natural Reserve

A FEW WORDS

Continued from page 1

The rate, scope, and magnitude of environmental degradation, the increasing rate of exploitation, and the drastic alteration of natural areas mandate a sustained effort to protect remaining such areas. A 1996 review of conservation theory asserted that "reserve design is one of the most fundamental tools conservationists have to protect, maintain, or enhance ecosystem function, heterogeneity or patchiness, and, ultimately, biological diversity." Indeed, this is the consensus view of many organizations, both governmental and nongovernmental.

For example, current documents on the planning of the terrestrial National Ecological Observatory Network (such as *NEON: Addressing the Nation's Environmental Challenges*," National Academy of Sciences, 2003; <**http://www.nap.edu/catalog/10807.html**>) showcase the critical importance of well-placed and well-designed networks of reserves in enabling research on the great contemporary environmental challenges. Ongoing efforts to establish national networks of marine protected areas also highlight the need for effective tools to guide the design of these reserve systems <**http://mpa.gov/pdf/national-system/final-framework-draft.pdf**>).

The period since the early 1980s has seen the development of many sophisticated software tools for conservation planning that provide a broadly based, realistic approach to the choice and design of sites for protected areas. The lead article in this issue of *Transect* offers a glimpse of these methods. Those interested in a current, comprehensive review should consult S. Sarkar et al.'s "Biodiversity Conservation Planning Tools. Present Status and Challenges for the Future," *Annual Review of Environment and Resources* (2006) 31:123-159.

— Alexander N. Glazer
Director, Natural Reserve System

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