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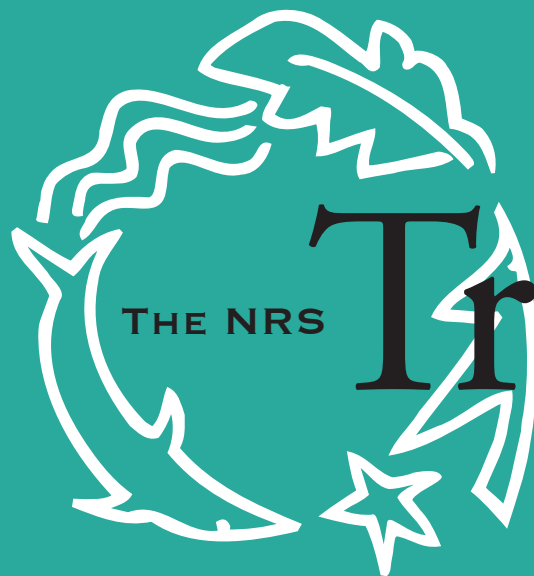
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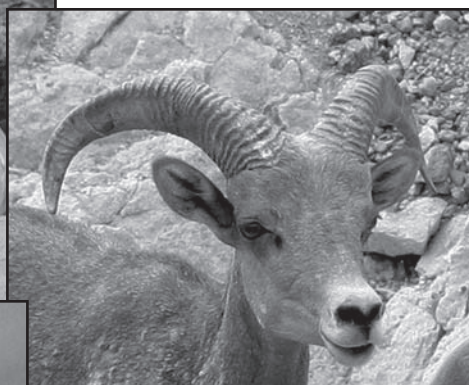
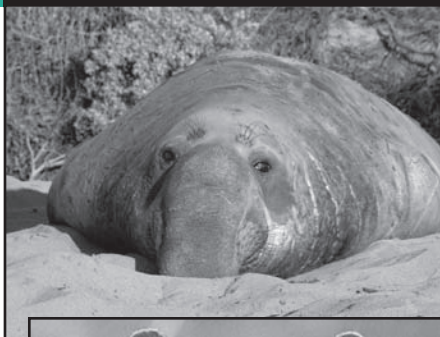
Transect

UNIVERSITY OF CALIFORNIA NATURAL RESERVE SYSTEM
OFFICE OF RESEARCH—DIVISION OF ACADEMIC AFFAIRS

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WHO'S YOUR DADDY? SCIENTISTS CONCERNED WITH THE LONG-TERM SURVIVAL OF THESE AND OTHER ENDANGERED SPECIES KNOW THEY NEED ANSWERS TO THIS CRUCIAL QUESTION. PHOTOS BY DAN COSTA (ELEPHANT SEAL), JULIA PERKINS (BIGHORN SHEEP), AND GARY ROEMER (ISLAND FOX)

HELPING ENDANGERED SPECIES TO KEEP THEIR FOOTING ON THE SLIPPERY SLOPE OF THE GENETIC BOTTLENECK

With a growing number of species going extinct or teetering on the brink, conservation biologists are concerned that even species that manage to increase their numbers will later succumb to sudden, devastating infections. Susceptibility to disease can be one consequence of genetic impoverishment—which may happen when a large, apparently recovered population has only a few forebears. But such low genetic diversity is thought to cause generally low species-fitness, resulting in lower reproduction and poor survival. This is why conservation genetics is becoming ever more important to scientists struggling to ensure the long-term persistence of endangered species.

A genetic bottleneck occurs when a species' population numbers decline to such a level that they are insufficient to maintain genetic diversity. The UC Natural

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GENETIC BOTTLENECKS

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Reserve System provides research access for three different species that either have experienced or are currently experiencing such bottlenecks: (1) island foxes (*Urocyon littoralis*) at Santa Cruz Island Reserve off the coastline of Ventura County, (2) desert bighorn sheep (*Ovis canadensis nelsoni*) at the Sweeny Granite Mountains Desert Research Center in San Bernardino County,* and (3) northern elephant seals (*Mirounga angustirostris*) at the Año Nuevo Reserve in San Mateo County.

The science beneath the surface

A species' genetic diversity is determined by the number of alleles — variants of specific genes within the overall genome — that are present across the population. Having multiple alleles available for each gene locus across a genome enhances a species' ability to adapt to environmental changes. Even in individuals that are heterozygous at a dominant locus (where two different alleles are present at a single locus, but only one is expressed), the retention of the recessive allele is important because it provides flexibility. Populations that are genetically variable at a given locus are referred to as polymorphic; those that lack diversity are called monomorphic.

When scientists gauge the genetic diversity of a species, their standard

**Note: The endangered peninsular bighorn sheep (*Ovis canadensis cremnobates*), a closely related subspecies, is also found at the NRS's Boyd Deep Canyon Desert Research Center in Riverside County.*

practice has been to look at microsatellite site locales. These short, highly variable DNA sequences distributed throughout a genome have little impact on an animal's fitness and therefore are under little or no selective evolutionary pressure. The combination of high variability with negligible selective pressure makes these sites ideal neutral markers for quantifying a species' relative genetic variability.

More and more, scientists are also looking at the major histocompatibility complex (MHC), a set of genes that determines an animal's disease resistance and influences kin recognition (and, therefore, reproduction). While microsatellite locales are neutral, because they have no impact on an animal's fitness, MHC locales are highly adaptive, subject to strong selective pressure by variation in pathogens, and have a direct impact on fitness and survival.

There is no direct correlation between microsatellite variability and MHC variability. Some species considered monomorphic, based upon microsatellite studies, are nevertheless diverse at the level of their MHC. The island foxes on San Nicolas Island in the southern Channel Islands, for example, are considered the most monomorphic sexually reproducing animal population ever recorded, based upon microsatellite analyses. But when Andres Aguilar, then a graduate student at UCLA, looked at five loci in the MHC, he found remarkably high levels of variation. "Neutral markers are still important for showing variability," Aguilar notes. "But in this post-genomics era, we're going to have more markers that are possibly fitness related, and using those is going to be very important for conservation and maintaining genetic diversity."



Captive breeders closely managed

The island fox (*Urocyon littoralis*), a scaled-down relative of the mainland gray fox, inhabits the six largest Channel Islands that lie off the southern California coast near Santa Barbara. Archaeological records and molecular genetic data indicate that foxes colonized the three northern Channel Islands (San Miguel, Santa Rosa, and Santa Cruz) about 16,000 years before present (B.P.), when a few gray foxes (*Urocyon cinereoargenteus*) washed ashore from the mainland. The animals adapted, as island species usually do, to the limited resources of their new habitat by becoming much smaller in size than their mainland ancestors. Many centuries later (between 4300 and 800 B.P.), Chumash traders, who were excellent seafarers, transported the now-diminutive foxes to the three southern Channel Islands (San Nicolas, Santa Catalina, and San Clemente). Over time, the fox populations on the different islands diverged sufficiently so that today each island has its own genetically distinct subspecies.

In the early 1990s, the fox populations on all three of the northern Channel Islands suddenly crashed. Scientists soon identified the problem: dramatically increased predation by a non-native golden eagle population that had moved over from the mainland (for more information, see *Transect* 20:2,

[Summer 2002], page 1). The island territory became available to the golden eagles after the native bald eagles, which would have driven the golden eagles away, were wiped out by DDT contamination. The bald eagles, which fed heavily upon fish, were vulnerable to discarded DDT that infiltrated the marine food chain; the golden eagles preferred to feed on tender, easily caught island foxes.

Fox losses were dramatic. The Santa Cruz Island population plummeted from 2,000 animals in 1993 to less than 100 only seven years later — a survival rate of less than 5 percent. On San Miguel Island in a similar period, numbers of foxes fell from 450 to just 15 — approximately 3 percent survival. And on Santa Rosa Island, they fell from 1,500 in 1994 to 14 animals six years later — less than 1 percent survival. UCLA Professor Robert Wayne, a specialist in canid genetics, explains how the situation developed and what the effect was: “The foxes were very naïve. They lived on the islands for thousands of years and were not used to having aerial predators swoop down and eat them. And their numbers weren’t really large enough to recover from this kind of threat, in a genetic sense. It was clear that they would be extinct before they mounted some behavioral evolutionary response to this new threat.”

On the advice of a scientific panel that included Wayne, the National Park Service (NPS) acted to save the remaining populations. In 1999, NPS captured all of the re-

maining foxes on both Santa Rosa and San Miguel Islands and brought them into pens where the animals would be protected from golden eagle predation. Two years later, working with The Nature Conservancy (TNC), NPS initiated a similar program on the much-larger Santa Cruz Island, bringing 12 animals into captivity and allowing between 60 and 100 foxes to remain in the wild. The strategy on Santa Cruz Island, where the NRS reserve is located, was to give the fox populations a chance to recover, while other teams of wildlife biologists worked to move the predatory golden eagles from the islands and to restore the native ecosystem (by reintroducing bald eagles and by removing feral pigs).

Genetics was the primary consideration for the captive-breeding program. NPS biologist Tim Coonan directs the Island Fox Recovery Program: “It’s the primary factor in all three of our captive-breeding programs. It determines what animals we put together, and it will also determine who gets released into the

field. When we pair animals together, it’s for genetic reasons. And when we release animals to the field, we’ll make sure that the loss of that animal won’t compromise the population’s genetic integrity.”

Designing a captive-breeding program while preserving as much genetic diversity as possible can be extremely challenging. This was especially true in the case of Santa Rosa and San

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TWO WILD ISLAND FOXES (ONE HELD BY RESEARCHER MELISSA GRAY), CAPTURED DURING TRAPPING EFFORTS ON SANTA CATALINA ISLAND IN THE SOUTHERN CHANNEL ISLANDS. ALTHOUGH SCIENTISTS DO WEAR PROTECTIVE GLOVES WHEN REMOVING FOXES FROM TRAPS, THE ANIMALS ARE FAIRLY DOCILE AND DO NOT NEED TO BE ANESTHETIZED. PHOTOS COURTESY OF MELISSA GRAY

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Miguel Islands, where each founding population consisted of fewer than 20 individuals. The usual method is to avoid kinship pairings. As Bob Wayne explains: “You want to pick individuals to breed who are maximally unrelated. You want to decrease the amount of inbreeding in the population to preserve the maximum amount of genetic variation and manage the whole genealogy genetically. But it’s a very small captive colony they’re dealing with, so their genetic management choices aren’t that great. They’ll have to tolerate some level of inbreeding.”

Maintaining diversity was especially challenging in the instance of the island fox, because, as is the case with most island species, each individual carries only a small fraction of the total genetic variability of the parental population. According to a study by Melissa Gray (one of Wayne’s graduate students), while mainland gray foxes have 75 percent heterozygosity at specific microsatellite locales, island fox populations on the nearby northern Channel Islands have only between 16 and 30 percent heterozygosity — roughly, between 20 and 40 percent of the genetic wiggle-room possessed by their larger cousins.

The second genetic challenge stems from the fact that small populations lose alleles simply because their numbers are low and subject to major fluctuations. When a population dips, the loss of even a few key individuals can mean the total loss of important alleles.

Gray’s master’s thesis on the relatedness of the island fox populations provided important clues for the breeding

program. “People often assume that all founding individuals in a captive-breeding population are unrelated because they’re from a wild population,” she explains. “But that’s actually not true, so you have to make sure you’re taking that into account when you’re doing your statistical analyses. In this case, we found that the founders of a subset were highly related, so we needed to make sure we were pairing them correctly.”

Using data assembled by Gray and other researchers, the park service established a detailed breeding strategy for each subspecies. The American Zoological Association, which keeps studbooks on endangered species held in zoos, also maintains a studbook on the island foxes. Each year they use a complex set of kinship formulas and analyses to identify the most appropriate matings.

Soon after the foxes were brought into captivity, however, a third problem emerged: not all of the foxes were breeding, and this further reduced the founding population. Coonan explains: “In captivity, you have some good breeders and some that are not so good. And the ones that are not so good are actually more important, because you don’t have their founder genes represented yet.” The question became why? Why were the nonbreeders not breeding? Was there a problem with the care the foxes were receiving? Was there a problem with how they were being confined? Or something else? Getting an answer quickly was crucial because nobody knew when the



WILD ISLAND FOX HUNTING ON SANTA CATALINA ISLAND. PHOTO COURTESY OF MELISSA GRAY

males would go into senescence and stop breeding entirely.

Fortunately, as adjustments were made, the previously uncooperative captive foxes did begin to breed. Then, as their numbers grew, a new question soon presented itself: which individuals should be released?

Just as captive breeding is carefully thought out to minimize inbreeding, so too, releases must be carefully considered to prevent the loss of rare alleles. “Each year they’ll have a number of candidates for release,” Wayne says. “But the advisory committee has recommended that they only release animals whose genes are well represented by other animals in the captive population, so if they’re lost, at least no valuable unique genetic component is lost along with them.”

Meanwhile, a complementary relocation program had reduced the number of golden eagles on the islands, but some birds were still present and could still be deadly. Releases of island foxes were successful in 2003-04. Of the 17 foxes released that season on San Miguel and Santa Rosa Islands, eagles killed only one, on Santa Rosa. In 2004-05, however, things didn’t go as well. Although, once again, no foxes were taken on San Miguel, eagles killed 5 of 13 foxes released on Santa Rosa. Losing nearly 40 percent of foxes painstakingly bred in captivity and released into the wild prompted the park service to initiate a *re-capture* program. However, as biologists began to pull the released foxes back in, they discovered that

some had already set up dens and were reproducing all on their own. The recall was cancelled.

Today the captive-breeding program for island foxes is in its seventh year and making slow but steady progress. Tim Coonan provides a brief report: "As of March 2006, there are 65 foxes for the San Miguel subspecies, including 39 in the wild. For the Santa Rosa subspecies, there are 68, including 34 in the wild. And on Santa Cruz, there are at least 150 in the wild — and that's a conservative estimate; there may be more than 200."

Even more significant, the foxes are not only surviving in the wild, but are also breeding in the wild on all three islands. Coonan, who has been working on this problem since 1999, is cautiously optimistic: "Depending upon how well they continue to breed, both in captivity and in the wild, the program could go on for six to eight more years on Santa Rosa and San Miguel. But on Santa Cruz, we might be able to get out of the captive-breeding business much more quickly."

The island fox isn't out of the woods yet. Even as their numbers increase, biologists will continue to monitor them. Wayne, Gray, and Coonan are currently collaborating on a test project that will allow them to estimate the populations by using scat samples. If their approach proves successful, the new process will allow them to estimate population sizes readily, without the time and expense involved in having to capture foxes and outfit each one with a radio collar.

For her part, Gray is currently expanding her study to include all subspecies and the entire genome. "I'm looking at the genetic basis for the fox's dwarfism,"

she says. "But, beyond that, I'm really interested in how this bottleneck has affected the foxes on a genomicwide level. Most studies look at only a handful of markers, between 10 and 20. My goal is to use the latest technology to go much larger, on the order of a couple of hundred markers, and get at what happens to a population overall. I'm definitely in this for the long haul."



Taking the high ground

Desert bighorn sheep (*Ovis canadensis nelsoni*) inhabit a number of small, isolated mountain ranges throughout the Sonoran, Mojave, and Great Basin deserts of the U.S. Southwest. They live in small populations of usually less than 100 individuals. In California, biologists estimate the desert bighorn sheep population at about 4,300, spread across a territory that extends from the White Mountains east of the Sierras to the Mexican border. Their numbers are relatively stable, but during the last 60 years, 30 of 80 populations within the state have gone extinct. To maintain the species, scientists have moved sheep into seven ranges where extinctions have occurred. Three

natural recolonizations have also been observed in recent years.

UC Berkeley postdoctoral researcher Clint Epps has spent much of the last six years tracking desert bighorn sheep throughout the California deserts. Epps often uses the Natural Reserve System's Sweeney Granite Mountains Desert Research Center as his base of operations. "I started my genetics work, right across the road (Interstate 40) from the Granites in the Marble Mountains," he says. "I had originally anticipated that I would sample maybe six populations, but as I discovered I could follow them with genetic tests, chasing the next ridge became a bit of an addiction. I ended up doing about 30!"

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TRACKING A RECOLONIZATION SOUTH OF THE BRISTOL MOUNTAINS IN SAN BERNARDINO COUNTY. CAPTURED BIGHORN SHEEP WILL DONATE BLOOD SAMPLES AND BE FITTED WITH RADIO COLLARS. PARTICIPANTS IN THIS EFFORT ARE (LEFT TO RIGHT): GEORGE KERR, VOLUNTEER FOR THE SOCIETY FOR THE CONSERVATION OF BIGHORN SHEEP; BOB TEAGLE, CAPTURE SPECIALIST FOR THE CA DEPARTMENT OF FISH AND GAME; AND CLINT EPPS, UCB POSTDOC WHO'S SPENT THE PAST SIX+ YEARS TRACKING BIGHORN SHEEP THROUGH CA'S DESERTS. PHOTO COURTESY OF CLINT EPPS

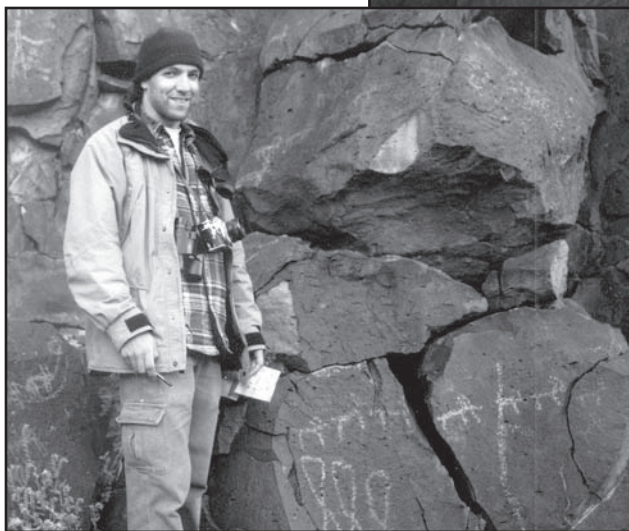


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(RIGHT) RESEARCHER CLINT EPPS ATOP OLD DAD MOUNTAIN. PHOTO BY JOHN WEHAUSEN

(BELOW) EPPS STANDS ALONGSIDE ANCIENT PICTOGRAPHS OF BIGHORN SHEEP IN THE WOODS MOUNTAINS. PHOTO BY MARY BETH REW



Epps's population genetics tests were conducted on the animals' fecal samples, which contain DNA. "I was really interested in the question of metapopulation dynamics, extinction, and colonization," he explains. "Colonization and dispersal have been difficult to study, because they're relatively rare. It doesn't take many individuals moving back and forth to maintain these processes, and the odds of detecting such movements are not very high. With genetics testing, we can match relatives and track individuals. In two cases, I detected the same sheep in two different nearby mountain ranges at different times, just from their droppings."

In studying the flow of genes across the desert, Epps discovered that genetic

diversity varies greatly between populations (based on results at 14 microsatellite loci). The Sweeney Granite Mountains bighorns, for example, are quite diverse and thus serve as a source population for recolonizing neighboring ranges.

"The Granites are high elevation, which makes them ideal territory for desert bighorns," Epps points out. "And they're well connected with the Providence Range, which, in turn, is connected to another small chain of populations. Taken together, this area is one of the most genetically diverse areas in the desert."

In the Newberry Mountains just outside of Barstow, however, the population's genetic diversity was found to be just half of that in the Granite Mountains population. Epps attributes this circumstance both to recent bottlenecks and to that population's geographical isolation. The Newberry Mountains animals live on an extremely remote range at the western edge of the territory, surrounded by long stretches of

flat desert. Epps has found that desert bighorns will cross about 5 to 10 kilometers of flat ground, but seldom go much further. Such isolation can be devastating to small populations.

Epps has identified two major human-created obstacles that interrupt the movement of animals between populations: freeways and canals. Freeways are often fenced to prevent cattle from wandering into oncoming traffic, but they also prevent bighorn sheep from finding one another as well. A freeway has cut off the Newberry Mountains sheep population from its only known source of new animals. Even in the Granite Mountains, the heart of bighorn sheep territory, freeways have had an impact, as Epps discovered early in his study.

"I found populations just to the south of the Granites that should have been within easy dispersal range," Epps recalls, "but an interstate built through the area in the 1960s cut off any interaction. And when I started working up my genetic samples in the lab, I noted that there was a surprising amount of genetic distance between these populations across the interstate



PHOTO BY JULIA PERKINS

and that the populations to the south were less genetically diverse. That's when I really started getting interested in the impact of the interstates. One reason I sampled so widely was to increase my sample size so I could make these comparisons."

Global warming is another major factor affecting the movements of bighorn sheep and their ability to intermingle dispersed populations. Over the last century, the mean annual temperature in southwestern U.S. deserts has risen by 1.8°F, while annual precipitation in California's deserts has dropped 20 percent. Epps believes these conditions are already affecting the region's bighorn sheep populations. "Losing 30 populations over the last 60+ years is an unsustainable rate of population extinction," he points out. "And those extinctions weren't random — they especially hit populations in lower, dryer ranges that lacked dependable springs. All of those are parameters related to climate." If global warming continues or even (as is often predicted) accelerates, the desert bighorn sheep population will become increasingly fragmented.

Epps is working on a number of possible solutions for the immediate problem of bighorn mobility. "One thing I'd like is to see what we can do about restoring the connectivity between the Granites and the Marbles to the south. The ideal thing for desert bighorn sheep would

be a big overpass, but the odds of that happening are pretty low. There are some large culverts in the pass where the interstate cuts across the north end of the Marbles, but they're fenced. I'm hoping CalTrans can open those back up."

"The Granites and the Providence Mountains and that region are really key," he continues. "To ensure the long-term persistence of desert bighorn sheep, you have to maintain those core areas and the connectivity with the more outlying areas. You don't want to give up on those outlying areas. If disease or mountain lions hit the higher, wetter populations, those peripheral populations might be the saving grace."

Epps also hopes land managers will use his research and that of his colleagues to guide their handling of the different populations of desert bighorn sheep. By understanding the flow of animals and genes between populations, land managers will be able to react quickly when a local bighorn population goes extinct. If the area is still connected, they can wait for it to be recolonized naturally. If the area is not still connected, they can bring in bighorns to get the population going again.

"It's crucial for each of these small populations to have new individuals come in from other populations," Epps explains.

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A GROUP OF DESERT BIGHORN SHEEP DISCOVERED NEAR A WATERING HOLE IN THE MARBLE MOUNTAINS. PHOTO BY JULIA PERKINS

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“Otherwise, you will eventually lose that population. That’s a standard feature of metapopulation models. The population may hang on for a long time, but if you don’t make it possible for new animals to move in, you’ll eventually lose these areas. You’ll always have populations winking out here and there, but the system as a whole should remain pretty stable as areas are recolonized. Disrupt that, however, and you run the risk of breaking down the entire system. The harsh environment inhabited by desert bighorn sheep already has them walking on a knife’s edge. It doesn’t take much to push them off. The bottom line is that more than one-third of the population that was once known is now gone, and we could lose them all.”



A monomorphic profusion

Burney Le Boeuf has been conducting research at the Año Nuevo Island Reserve, off the Santa Cruz coast, for almost four decades. It was 1968, just a few years after the northern elephant seals began having pups on the island, that he and a few other scientists started their investigations. Over the next nearly 40 years, Le Boeuf, his colleagues, and his students would lead the way in demystifying the lives and lifestyles of these giant animals who spend months



A TRUMPETING MALE NORTHERN ELEPHANT SEAL ASSERTS HIS DOMINANCE.

PHOTO BY DAN COSTA

in the open ocean. “They really live in two worlds,” Le Boeuf explains. “For much of the year, they’re in the open ocean, diving to great depths, dealing with high pressure, darkness, and cold. At other times, they come ashore to reproduce on land.”

Long-term studies conducted by Le Boeuf and his colleagues have revealed much about the elephant seals — their history, feeding patterns, mating strategies, vocalizations, annual travels, factors that determine the health of pups, and ways they deal with oceanic changes. But for all of these scientists’ successful accomplishments, one common area of biological research has always been closed to them: they’ve never been able to determine kinship or conduct parenting studies.

Le Boeuf seems wistful as he recalls this long quest: “It goes back to a seminal 1974 study by one of my former graduate students, Michael Bonnell, who worked with Robert Selander on what was, at the time, a state-of-the-art paternity study. I was interested in their work because northern elephant seals

are one of the most polygynous of all the mammals ... just a few males do the majority of the breeding. And I wanted to document whether the discrepancy of paternity in the colony was similar to the monopoly that we saw in mating behavior. Were the few animals you see mating *also* siring all the pups?”

Unfortunately, Selander and Bonnell’s study revealed it was impossible to determine a pup’s parentage, because, at the genetic level, all pups look pretty much identical. This makes a lot of sense when the species’ history over the last couple of centuries is considered. European seal hunters arrived in the Pacific Ocean to find about 300,000 northern elephant seals living in colonies from Mexico into Canada. The seals were highly valued for their oil, and, throughout the 1800s, sealers decimated them. By the 1880s, almost all of the elephant seals were gone. Scientists estimate their effective population during that nadir at less than 40 individuals, perhaps only 20 to 30, all of which were located on Guadalupe Island off the coast of Mexico.



SCIENTIST BURNEY LE BOEUF AT AÑO NUEVO ISLAND RESERVE.
PHOTO COURTESY OF BURNEY LE BOEUF

Yet, from this extreme bottleneck, the elephant seals have made a dramatic comeback. Their numbers are currently estimated to exceed 175,000. Año Nuevo* provides a perfect example. In 1968, scientists counted 140 breeding females on the island; now each year, between 2,500 and 2,600 breeding females come ashore — and even more can be found on the nearby mainland beach. Moreover, elephant seal rookeries dot the coast from Mexico to central California, most recently the Farallon Islands and Point Reyes. Le Boeuf notes that the only thing that has delayed this northward spread is the lack of suitable islands along the coastlines of northern California, Oregon, and Washington. He's confident, though, that the process will continue. "I wouldn't be surprised to see them breeding on Vancouver Island in

the near future," he says. "Maybe even further north."

However, while the numbers of elephant seals have increased dramatically, scientists fear the vulnerabilities of their genetic bottleneck remain. "Clearly, they lost some variability when the axe fell in the 1800s," says Le Boeuf, "but what's hard to know is whether there were similar events that reduced variability before that bottleneck."

As genetic techniques have improved over the last 20 years, a number of other scientists have

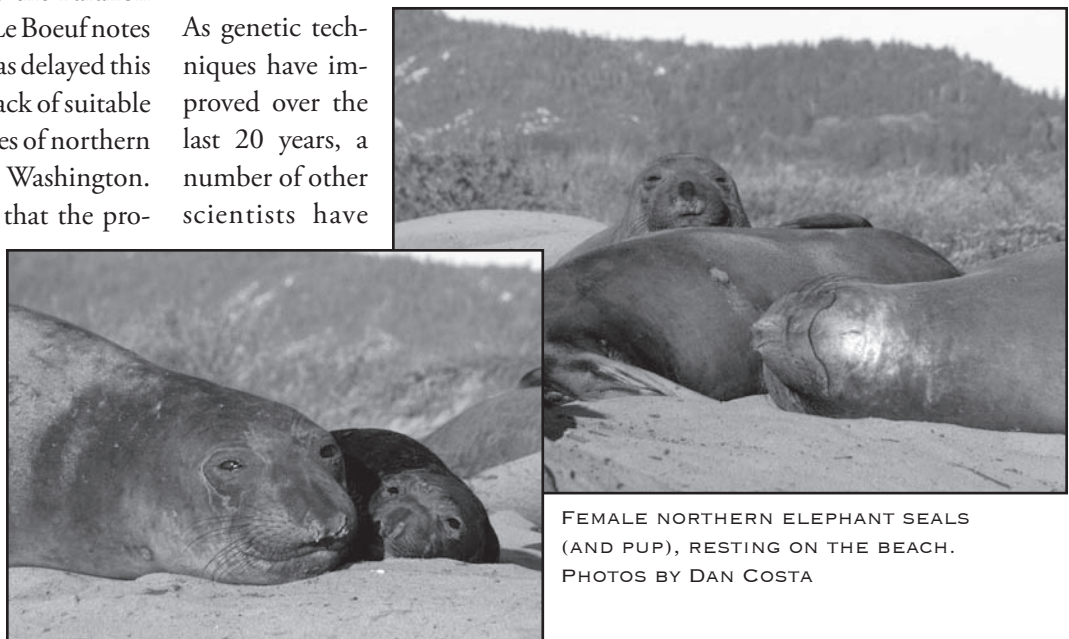
attempted paternity studies. All have proven unsuccessful. "We pursued it in the hope that DNA fingerprinting would allow us to do that," Le Boeuf explains. "That didn't work, because we didn't see sufficient differences among males to separate one potential father from another. Next we tried mitochondrial DNA, but found nothing there either."

Figuring that the problem stemmed from simply needing more probes, another one of Le Boeuf's graduate students, Michelle Weinstein, began a study on both the northern elephant seal and its close relative, the southern elephant seal. As Le Boeuf recalls: "She ended up doing her thesis totally on the southern elephant seals. She didn't do the northern elephant seals, because she couldn't find differences between the males. And that situation still exists today. We could never do that study."

Out of frustration, Le Boeuf's group resorted to nongenetic techniques for their paternity study. Le Boeuf confirms

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*Note: Año Nuevo Island Reserve is managed by the NRS, owned and operated by the CA Department of Parks and Recreation.



FEMALE NORTHERN ELEPHANT SEALS
(AND PUP), RESTING ON THE BEACH.
PHOTOS BY DAN COSTA

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that now they “estimate paternity using probability and other techniques, and the answer is yes, in both northern and southern elephant seals, the male who is doing most of the mating is responsible for most of the paternity.”

The most surprising aspect of this particular genetic bottleneck is that lack of variability doesn’t seem to have reduced the elephant seal’s fitness. Some scientists suggest the species might even have become adapted to low genetic diversity. But Le Boeuf finds that idea hard to fathom: “It doesn’t make much sense to me that they would be adapted to low genetic variability. I think it’s much more reasonable that the variability has been reduced because of their history.”

Genetic theory says that the best hedge against an uncertain future is to produce genetically variable offspring because, as conditions change, some individuals will do better than others. But the northern elephant seal has not diversified its portfolio of genetic investments. So far, that strategy has worked. Will this be true in the future? Le Boeuf is philosophical: “When we were dumping DDT off the southern California coast, the elephant seals and other deep-diving marine mammals weren’t affected. We did see high levels of mercury and lead, but that didn’t seem to bother them. I guess it just depends on what kind of pollution, and who knows? — there might be a by-product of something we start using tomorrow that goes into the ocean and hits them hard. You don’t know.”

Individual species — individual solutions

Although past human disregard for the survival of individual species is responsible for the present endangered status of the island fox, desert bighorn sheep, and northern elephant seal, the question of how to support these species so they may persist in the world of the future presents a different scientific challenge in each case.

The island fox’s genetic bottleneck was brought on when humanmade disruptions in their Channel Island habitat led to increased predation by another species that might never have become a problem in a healthier, more balanced environment. Now the foxes survive through carefully monitored rescues and captive breeding designed to encourage genetic diversity. The current solution to this genetic bottleneck requires constant monitoring of predation and survivorship of each subspecies.

Some hands-on stewardship has also been applied successfully to the desert bighorn sheep. It was discovered, however, that the bighorns, despite living in small herds in isolated mountainous areas spread across the Mojave Desert, make an effort to maintain their own genetic diversity: individual animals cross miles of lowland desert to reproduce with new herds. Scientists who follow the flow of genes across the desert have learned that they may be able to best help this species by informing management decisions that, in turn, either remove obstacles (such as freeways and canals) from bighorn reproductive migration routes or enable the animals

to circumnavigate the obstacles. Scientists can also help by influencing the decisions that corporations and nations make that affect global warming.

Finally, the northern elephant seals, hunted to near-extinction during the nineteenth century, have rebounded on their own into the twenty-first century. At this point, they seem well adapted. However, because the entire huge population is descended from a very few founders, scientists worry that lack of genetic diversity may eventually doom the species. All that can be done in the case of the elephant seals is to monitor and study them in order to understand better how they have managed to recover and even to thrive — and to hold the intention to protect the species, should further threats present themselves. — JB

For more information, contact:

The National Park Service

Island Fox Recovery Program
<<http://www.nps.gov/chis/naturalresources/IslandFox/Fox.htm>>

Clinton W. Epps

Environmental Science, Policy,
and Management

College of Natural Resources

University of California

Berkeley, CA 94720

Email: buzzard@nature.berkeley.edu

Burney Le Boeuf

Associate Vice Chancellor

for Research, and

Research Professor of Biology

283D Clark Kerr Hall

University of California

Santa Cruz, CA 95064

Email: leboeuf@ucsc.edu

NEW STUDY SUGGESTS ONE WAY TO CONTROL INVASIVE ANTS

California's mild Mediterranean climate suits Argentine ants just fine. They have thrived here since their arrival during the early 1900s. Over the last 40 years, however, concurrent with large tracts of arid coastal scrub being transformed into well-watered subdivisions, Argentine ants (*Linepithema humile*) have multiplied to wreak havoc within both native ecosystems and suburban homes.

But a recent study by two UC San Diego biologists, Assistant Professor David Holway and his doctoral student Sean Menke, has revealed an important way to control these pesky invaders:

Turn off the water.

Following an investigation conducted at two NRS sites — Dawson Los Monos Canyon Reserve and Elliot Chaparral Reserve — and three other protected San Diego County locales, the researchers are now offering the first experimental evidence that controlling soil moisture limits invasions of Argentine ants. The scientists reported their results in the March 2006 issue of *Journal of Animal Ecology*.

Biologists have long thought that these tiny, dark-brown ants need moist soils to live and breed. They suspected that limiting water could play a key factor in curbing the ants' spread, but controlled experiments had never been performed.

Working at five ecologically different sites throughout San Diego County, Holway and Menke manipulated soil moisture with drip irrigation for six months during the dry season, from



THIS WORKER ARGENTINE ANT WAS PHOTOGRAPHED IN DAVIS, CA, BUSILY TENDING A SCALE INSECT ON A CITRUS PLANT. PHOTO BY ALEX WILD

May to October. After three months, they found that Argentine ants expanded nesting sites by 54 percent in irrigated sites and decreased them in control sites. And when they shut off the water, the ants retreated, returning to nearly pre-experiment levels after three additional months.

Because irrigation also increases plant growth, the researchers used herbicides to suppress plants on selected plots. Although ants primarily respond to elevated levels of soil moisture, ant populations were 38 percent higher in irrigated plots with vegetation than in plots without plants. They theorize the increase was due to the presence of aphids that provided a new food source for the ants.

Argentine ants are often associated with disturbed habitats. However, they readily invade natural habitats, aggressively displacing native ants. In trying to determine what makes some communities more susceptible to invasion than others, most studies have focused primarily on species diversity. Consideration of physical characteristics has been limited to large-scale climate studies. This study was a unique attempt to look at how abiotic factors contribute to patterns of invasion at a community level.

So, what are the implications for homeowners and land managers? "The results are clear," Holway says. "If you have wet soil outside your home, if you irrigate your yard frequently, you're providing an environment that may be attractive to Argentine ants. And land-use managers who have to deal with streams of irrigated water or urban runoff should reduce or contain that runoff as much as possible. If they can do that, problems associated with Argentine ants should diminish."

On a larger scale, Holway's career is focused on the study of biological invasions in general and, in particular, why some ecological communities are relatively immune to invasion, while others are wholly transformed by it. As he explains: "Developing a comprehensive understanding of the factors governing community-level vulnerability is tremendously important, because non-native species are threatening ecosystems worldwide. Argentine ants provide an ideal subject for our studies, because their invasion fronts are spatially discrete and can be accurately measured — allowing us to study these issues from a number of perspectives." — JB

For more information, contact:

David Holway
Division of Biological Sciences
University of California, San Diego
MC 0116, 9500 Gilman Drive
La Jolla, CA 92093-0346
Phone: 858-822-5207
Email: dholway@ucsd.edu

CALIFORNIA BEETLES GO ONLINE

When Michael Caterino came to UC Berkeley as an entomology graduate student in 1992, he was anxious to get to know the beetles: “California’s beetle fauna is renowned for having unusual things that you can’t find other places, a lot of relict species, living dinosaurs, so I was always out collecting.”

What he probably didn’t realize at the time was that California beetles would become his career. Years later, when he interviewed for a job as the first full-time entomology curator at the Santa Barbara Museum of Natural History, he mentioned an idea he had—to develop a California Beetle Project. “I had been thinking about how many beetles there were and how poorly they were known. So I started cooking up this idea and soon realized how badly it was needed. There are huge holes in what we know about what’s really the most diverse group of organisms in the state. There’s something like 8,000 known species of beetles here, which puts them far beyond any other group, even flowering plants. And that’s probably only 80 percent of what there actually is.”

The committee liked his idea. They hired Caterino, and, for the last five years, he’s been working diligently on the project. Just over a year ago, the National Science Foundation gave him a five-year grant to accelerate the work, allowing him to assemble a staff that includes a postdoctoral researcher, four part-time employees, and three to four volunteers.

In March 2006, the team achieved a major milestone: they launched the online California beetle database, with over 50,000 records—all searchable by

species and locales. “The site provides specimen-level data and mapping capabilities for records from our museum collection,” Caterino explains, “as well as a significant amount of published literature. And it’s growing daily.”

Caterino’s sampling expeditions have taken him to a number of NRS sites, including all the reserves in the Santa Barbara area. He describes his investigations: “I’ve done significant work at about ten reserves altogether, ranging from the James [San Jacinto Mountains] Reserve [in Riverside County] to the [Landels-Hill] Big Creek Reserve [in Monterey County]. The system is a great resource for entomologists. I had traps running at Sedgwick Reserve [in Santa Barbara County] for a continuous year, checking them every couple of weeks. You’d think that, after a year, you’d pretty much have everything. But every time I went, even at the end of a year, I was finding something I hadn’t seen before. [UC Berkeley Professor] Jerry Powell has been collecting moths annually at the Big Creek Reserve for fifteen years, and every year something new pops up.”

At the Coal Oil Point Natural Reserve, just a few miles from his Santa Barbara office, Caterino worked with reserve Director Cristina Sandoval to compile a complete online insect field guide for that site. “Cris is well known for her walking-stick research, so I was very interested in working with her,” he explains. “We received a Pearl Chase Fund grant,* which allowed us to hire and

**Note: From the Doctor Pearl Chase Fund for Local Community Development Research Projects, UC Santa Barbara Academic Senate.*



PLEOCOMA BADIA HIRSUTA, ONE OF ABOUT 30 MEMBERS OF THE GENUS *PLEOCOMA* IN CA. PHOTO BY MICHAEL CATERINO

train undergraduates to make the collections, identify and prepare the specimens, and put it all online.” The results of their work can be seen at: <http://www.sbnature.org/collections/invert/entom/COP/COPbugshome.php>.

Now that Caterino’s California beetle database is online, his team is integrating photographs with data and developing short natural histories for as many specimens as possible. He says: “We have a lot more to do, especially because we want to make this useful for everyone. Our ultimate goal is to make it more a field guide than just lists of species names and locales.”

The home page for the California Beetle Project can be found at: <http://www.sbnature.org/calbeetles>. The database is located at: <http://www.sbcollections.org/cbp/cbpdatabase1.aspx>. —JB

For more information, contact:

Michael Caterino
Curator of Entomology
Santa Barbara Museum of Natural History
2559 Puesta del Sol Road
Santa Barbara, CA 93105-2998
Phone: 805-682-4711, X151
Email: mcaterino@sbnature2.org

CHUMASH SUMMER CAMP AT SEDGWICK RESERVE REALIZING LONG-HELD DREAM OF CULTURAL REVIVAL

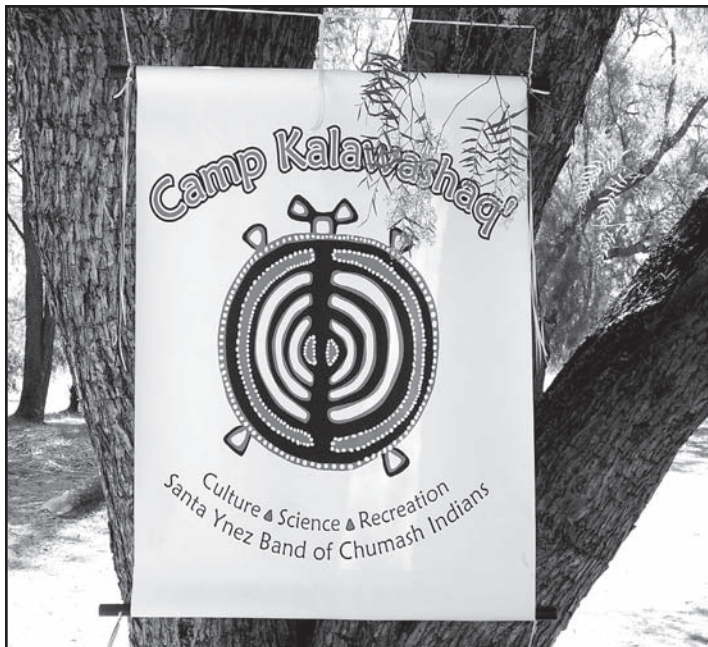
As the days get longer, the air warms, and plants emerge from their winter dormancy, Fred Loveys starts to think about the upcoming summer. For the last three years, Loveys, an Englishman and the director of education for the Santa Ynez Tribe of the Chumash Indians, has worked with tribal leaders and outside experts to put together a six-week summer camp program that introduces Chumash children, ages 6 through 16, to their culture and to science.

Camp Kalawashaq' ("Keepers of the Shells," a reference to the currency once used by the Chumash) mixes serious cultural lessons—traditional Chumash dancing, songs, crafts, construction techniques, and language—with summer fun, like swimming, sports (with a Chumash twist), and days at local theme parks and points of interest. On top of this, the students also explore science, visiting a marine science research vessel at UC Santa Barbara, touring the collections at UCSB's Donald Bren School of Environmental Science and Management, and learning about outdoor habitats, from coastal tide pools to upland streams.



The home base for many of these activities is the NRS's Sedgwick Reserve. A creekside bench of land on the reserve has become a construction site where the children work on a traditional Chumash reed home. The art studio once used by sculptor and reserve donor Duke Sedgwick now serves as a classroom where the students create clappersticks and drums, and design their own dance regalia from buckskins and shell beads. The abandoned agricultural fields near the reserve headquarters serve as demonstration sites for Chumash hunting skills, as well as playing fields for Chumash games. Tall California pepper trees cool the reserve complex during the summer, and, as Camp Kalawashaq' draws to completion, they also provide protection for the dance circle where children and adults gather for a closing ceremony.

When the Chumash Education Committee approached Loveys in 2000 with the idea of designing a summer program, the Culham College, Oxford-educated, former Outward Bound instructor was intrigued: "I was impressed by their commitment to education and to kids. They wanted a summer camp experience unlike any other, one that was rooted in Chumash culture. From an outsider's perspective, I thought, this is an important job because the students were facing a cultural challenge fitting into the schools. It struck me that we should see what we



ALL PHOTOS ACCOMPANYING THIS ARTICLE ARE REPRODUCED WITH PERMISSION FROM THE SANTA YNEZ BAND OF CHUMASH INDIANS.

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CHUMASH SUMMER CAMP

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could do in the summer to root them in their culture, while also giving them a sense of the land.”

Chair of the Tribal Education Committee Sarah Moses explains the tribe’s objectives: “Growing up, we never had this opportunity. So now that we have the resources to help the kids out, that’s what we’re trying to do. We want to encourage them to further their education, know more about their heritage, and make their own regalia.”

The tribe’s goals meshed perfectly with those of the University of California. As Joe Castro, executive director for campus outreach initiatives at UC Santa Barbara, notes: “One of the University’s missions is to serve all of the communities of the state. So UCSB tries to fulfill that role by establishing partnerships with communities in our region. This partnership is especially important to us because it gives us an opportunity to work with American Indian children and create new opportunities for them to go on to higher education.”

The camp wasn’t an instant success. “The first year,” Loveys recalls, “was tough. We only had six to eight kids, and we were still developing the program. But Adelina Alva-Padilla, the tribe’s spiritual leader, told us to be patient, that we were planting the seeds. And she was right. That first year, we established the format: culture, environmental science, and fun — and each year the program has grown. Now we have up to 40 students participating, and I’m confident it will continue to grow.”



KALAWASHAQ’ KIDS CONSTRUCTING A TRADITIONAL CHUMASH DWELLING CALLED AN *AP*. “IT’S HARD WORK!” ONE CAMPER OBSERVED. PHOTOS COURTESY OF THE SANTA YNEZ BAND OF CHUMASH INDIANS

The Chumash would seem to agree that it takes a village to educate a child, for they’ve assembled a remarkable staff of both Chumash and non-Chumash educators to develop the Camp Kalawashaq’ program. Paul Gelles, a former UC Riverside anthropology professor now teaching at a local middle school, serves as the camp’s cultural coordinator. “I’m not Chumash, and I’m not an expert in Chumash culture,” he says. “My role is to get the elders and community members involved in teaching their culture and to coordinate with outside experts to educate the kids.”

One teaching role that Gelles takes on directly is making the children aware of the “spiritual geography” that surrounds them. “The tribal elders and spiritual leaders know these sites well,” Gelles explains, “so we take the kids to historical village sites at Sedgwick, at Vandenberg Air Force Base, at Santa Cruz Island to talk about what life was like. We want to give them a sense of the extent of Chumash land, that it stretched from Malibu to San Luis Obispo and out to the Channel Islands, so they understand that their ancestors were sophisticated people with extensive trade networks who laid claim to this extensive area.”

The tribe also brought in Kathy Conti as cultural program advisor for the camp. Conti, an 18-year veteran of the Santa Barbara Museum of Natural History where she specialized in Chumash culture, draws upon a large network of cultural experts. She brought teacher Mark Mendez up from San Diego to teach the kids how to make clappersticks, deer-hoof rattles, and walnut-shell dice. Survival expert Joe Dabill came down from northern California to demonstrate hunting with an atlatl, starting a camp fire using mule-fat sticks, and other life skills. Storyteller Julie Tumamait joined the children on an overnight trip to Santa Cruz Island to share Chumash tales.

Another expert helped the kids make soapstone pendants using sharkskin as sandpaper.

Though she’s not Chumash, Conti learned many of her skills from Chumash elders who have since passed away. She views herself as a temporary holder of the flame, giving this knowledge back to the Chumash so they can then teach succeeding generations. She was particularly impressed with

how seriously the children took the regalia workshops. “You can’t teach respect, you can only engender it,” she says. “When you put the regalia on for a dance, there are certain standards you must observe. The kids sensed that and acted accordingly. The Chumash people, both adults and children, are thirsting for culture. Today they’re not struggling to survive, so they can make a place in their life once again for culture. Once they connect on that cultural journey, there’s no way to stop them.”

Willie Wyatt, a Chumash leader who serves as the tribe’s environmental manager, worked with Conti in the regalia workshops and led the students in their dances. A graduate of UC Davis, Wyatt has long immersed himself in tribal lore and now teaches the students by drawing upon the things his elders taught him. “The kids were really interested in learning the songs and making regalia,” he notes. “And they’re so brave to get up at the closing ceremony, and sing and dance in front of a group of adults.... That tells me they’re really proud of their heritage. They see their community coming together to offer them a precious gift, so they take it seriously.”

Sports and outside activities constitute a major part of the Camp Kalawashaq’ program. The kids come to camp expecting to have fun, and it’s up to Chris Lasaca, a Chumash descendant from northern California, to make sure they aren’t disappointed. Lasaca, a baseball coach in San Jose for 18 years, had been unaware of his Chumash heritage until he was contacted by the tribe. As the recreation coordinator for the camp, he has put together a program that includes traditional Chumash games. He smiles as he admits that he had to learn some of the games along with the kids. Then he mentions one favorite game: “The kids really enjoyed shinny or tikauwich. It’s a game similar to field hockey, only with really hard sticks, an oval rock instead of a ball, and a 300-yard-long field. In the old days, villages would play against neighboring villages in tournaments.”



CHILDREN AT CAMP KALAWASHAQ’ GAIN INSIGHT INTO THE LIVES OF THEIR FOREBEARS BY RE-ENACTING SUCH ANCIENT TRADITIONS AS PADDLING A *TOMOL* (ABOVE) AND SINGING CHUMASH SONGS WHILE WEARING CEREMONIAL REGALIA THAT THEY THEMSELVES CREATED (RIGHT). PHOTOS COURTESY OF THE SANTA YNEZ BAND OF CHUMASH INDIANS



Lasaca and the camp staff adapted the game with softer balls, a smaller field, and modern field hockey sticks — then let the kids play. “Physical sports with lots of contact were a big part of Chumash culture, and most of these kids really thrive on it,” Lasaca explains, before adding, with another smile, “Besides, it’s a great way to tire them out.”

Teacher Larry Madrigal coordinated the final component of Camp Kalawashaq’: the science program. “Our goal was to use hands-on activities to make children more aware of the natural world,” he says. “So we had them build terraria and aquaria with small animals and fish they could catch at Sedgwick. The kids loved catching the animals and then observing them. A lot of our ideas were adapted from the *Kids in Nature* program that takes place at the reserve during the school year” (for more information, see *Transect* 21:1 [Spring 2003], page 12).

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CHUMASH SUMMER CAMP

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Other adult tribal members have also been willing to share their expertise. One parent, Tom Lopez, showed the kids how to surf fish. Another group showed them how to build and paddle a *tomol*, the log-plank boats the Chumash used for long ocean crossings to the Channel Islands.

But not only adults contribute to make Camp Kalawashaq' a success. Chumash high school and college students serve as both camp volunteers and paid interns. Some know the tribal traditions, while others learn almost as much as the students they're watching over. "I didn't grow up on the rez," says intern Marci Valencia, "so I've learned the cultural things at camp along with the kids."

And what do the Kalawashaq' kids get out of the program? Another intern, Josephine Alinaya, explains, striking a philosophical note: "The kids get whatever they're ready to receive. We don't force them to do anything, because not doing it right would be worse than not doing it at all. For one seventh-grader, seeing the dolphins on the way out to Santa Cruz Island made the difference — now she wants to be a marine biologist. For some younger boys, it was catching crawdads in the stream and playing shinny. For a lot of kids, making their own regalia and learning the dances count most."

To an outsider, it's apparent the children have a strong awareness and pride in their Chumash culture. At the closing ceremony for last year's camp, the students performed a number of dances and songs for the tribal elders, filling the air with the rhythm of clappersticks, deer-hoof rattles, and dancing feet. This was the first time most of the children had performed in their dance regalia, and the event served as a milestone on the path of the tribe's journey toward cultural renewal.



CAMPERS POSE FOR A GROUP SHOT FOLLOWING THEIR DANCE PERFORMANCE AT THE CAMP KALAWASHAQ' CLOSING CEREMONY. TRIBAL ENVIRONMENTAL MANAGER WILLIE WYATT (FAR RIGHT) LED THE CHILDREN IN THE DANCE. PHOTO COURTESY OF THE SANTA YNEZ BAND OF CHUMASH INDIANS

The dancing was followed by an equally remarkable moment when the students counted to ten in Chumash. This simple act was loaded with significance, because there are no living Chumash speakers. Searching to recapture their voice, the tribe located a linguist in northern California, Richard Applegate, who drew upon the notebooks of early anthropologists who carefully recorded Chumash words. The goal is to create a dictionary, teach classes, and revive the language. The students' halting recitation was another step on their journey.

As she walked to her car after the closing ceremony, tribal spiritual leader Alva-Padilla seemed in awe of the moment. "This is everyone's dream," she said. "Once the children start singing our songs and speaking two or three words of our language, that touches our hearts. I believe good things come to you when you're ready to receive them. Right now we're giving the kids little pieces. It might take 40 years, but someday they'll be ready, and they'll look back and say, 'We started this.' This has been our dream. I believe in dreams." — JB

For more information, contact:

Fred Loveys, Director of Education
Santa Ynez Band of Chumash Indians
P. O. Box 1234
Santa Ynez, CA 93460
Phone: 805-693-8317
Email: floveys@santaynezchumash.org

NRS WRAPS ANOTHER SUCCESSFUL MATHIAS SYMPOSIUM AT BODEGA MARINE RESERVE

The NRS's Mildred E. Mathias Graduate Student Research Grants support the work of some of the most promising young field researchers from throughout the UC system. Every other year, these students gather to share their research results. The 2006 Mathias Symposium was held February 24-26 at the Bodega Marine Laboratory and Reserve on Bodega Head in Sonoma County, 50 miles north of San Francisco.

The three-day event included student presentations as well as talks by two special faculty lecturers, both of whom incorporate a paleontological perspective into their research. Carole Hickman, of UC Berkeley's Integrative Biology, who has been involved in the reserve system since its earliest days, discussed her investigations into the metazoan life in seagrass ecosystems. Kaustuv Roy, co-faculty director for UC San Diego-administered NRS reserves, spoke about the impact of climate change and human activities on California's coastal ecosystem.

The 20 student presentations explored a wide variety of topics — from ecology, animal physiology, and marine science to history, engineering, and geography. This diversified mix of specialties made for a lively exchange of information and ideas during the post-talk discussions and informal breaks. The student talks impressed Hickman with both their consistent quality and the multiplicity of subjects considered. She said: "At most scientific meetings, you spend all of your time in one specific subgroup. The range of talks here is wonderful. I've definitely picked up some new ideas that might influence my own research." — *JB*



MATHIAS LECTURER CAROLE HICKMAN (UCB)



EXAMINING LIFE ON THE ROCKS AT BODEGA MARINE RESERVE: (CLOCKWISE FROM FAR LEFT) GRANT RECIPIENT JEFF HOWARTH (UCSB); GRANT RECIPIENTS ADRIAN ROCHA (UCI) AND ELISE FERREE (UCSC); MATHIAS LECTURER KAUSTUV ROY (UCSD); GRANT RECIPIENT LEO SZUMEL (UCD)



ALL PHOTOS FROM THE
2006 MATHIAS SYMPOSIUM
BY
MIKE DORWARD



MCLAUGHLIN RESERVE IN WINTER AND IN SPRING.
PHOTOS BY CATHERINE KOEHLER



GOLD COMPANY'S MILLION-DOLLAR ENDOWMENT IMPROVES DAILY LIFE AT MCLAUGHLIN RESERVE

On November 30, 2005, Barrick Gold of North America, Inc. announced a gift of one million dollars to the NRS's Donald and Sylvia McLaughlin Natural Reserve. The gift establishes the Barrick-McLaughlin Legacy Fund, to support operations and maintenance at the 7,050-acre reserve, which spans the borders of Napa, Lake, and Yolo Counties.

Susan Harrison, campus director of the UC Davis reserves, was thrilled with the news: "This endowment is unique, because it funds ongoing maintenance. That frees the reserve's co-directors, Cathy Koehler and Paul Aigner, to focus more on writing grant proposals for expanded facilities and educational programs, and less on day-to-day chores, like utilities issues and patrolling for trespassers. Until now, they've been too busy with low-level things to plan for the future as much as they could."

Aigner agrees with that assessment. Noting that income from the endowment will more than double what had been the reserve's operating budget, he added: "It definitely changes our plans for the future. We will be able to accelerate a number of projects, including the creation of an on-site residence for the reserve steward."

Barrick Gold Corporation is the parent company of Homestake Mining Company, which operated a gold mine and processing plant on the land from the mid-1980s through 2002. During that time, Homestake extracted more than three million ounces of gold from the property. In 1993, the mining firm signed a contract with the University of California to create a 300-acre reserve. The remaining acres were added to the reserve by a Use Agreement signed in early 2003.

This partnership is unique for the company, according to Be-Be Adams, manager of community and government relations for Barrick Gold of North America (which manages operations in the North American region of the international Barrick Gold Corporation). "When we acquired Homestake [in 2001], we acquired their obligations," Adams explained. "We went out and took a look at the reserve and decided it was a great opportunity to work with an organization [that] a mining company wouldn't normally work with. And we wanted to make sure that partnership was successful."

The McLaughlin Reserve is one of the few sites in California with protected serpentine habitats. About one-third of the land is covered by harsh serpentine soils that host specially



BE-BE ADAMS, BARRICK GOLD CORPORATION'S MANAGER OF COMMUNITY AND GOVERNMENT RELATIONS, STANDS ALONGSIDE BARRY KLEIN, VICE CHANCELLOR FOR RESEARCH AT UC DAVIS, ON THE OCCASION OF THE CREATION OF THE BARRICK-MC Laughlin LEGACY FUND. PHOTO BY ANN FILMER

adapted plants and associated insects. Located on the boundary of the Putah and Cache Creek watersheds, about two hours' drive northwest of the Davis campus, and surrounded largely by publicly accessible state and federal land, the reserve also features woodland and grassland habitats and mineral springs. Native animal species range from dozens of varieties of butterflies to black bears, mountain lions, and peregrine falcons. —JB

For more information, contact:

Paul Aigner and Cathy Kohler

Resident Co-Directors

McLaughlin Reserve

26775 Morgan Valley Road

Lower Lake, CA 95457

Phone: 707-995-9005

Email: mclaughlin@ucdavis.edu

UC researcher perishes in an attempt to rescue two colleagues

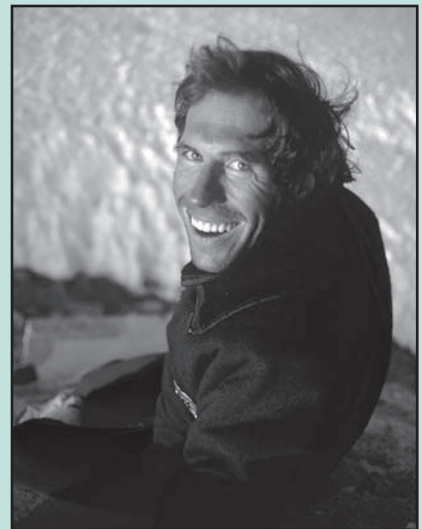
A UC Santa Barbara researcher was one of three men who died at Mammoth Mountain on Thursday, April 6, 2006. Charles "Walter" Rosenthal succumbed to fumes from a volcanic gas vent on the flank of the mountain when he went into a deep hole in the snow to rescue two fellow Ski Patrollers, James Juarez and John "Scott" McAndrews, who had fallen as they tried to rope off the unsafe area. Rosenthal was an Assistant Specialist with UCSB's Institute for Computational Earth System Science. He worked out of the Sierra Nevada Aquatic Research Laboratory (SNARL), part of the NRS's Valentine Eastern Sierra Reserve.

Rosenthal was born and raised in Burbank, CA. He graduated from UCLA with a degree in Political Science and moved to the eastern Sierra. He worked for the Mammoth Mountain Ski Patrol for 30 years and was the lead avalanche forecaster. Recognizing his unusual talents, UC Santa Barbara Professor Jeff Dozier lured Rosenthal into an M.S. program in Geography in 1991. Rosenthal and Dozier remained colleagues and had recently been awarded a large grant to study the sintering of snow crystals, a process of snow metamorphosis in which the crystals begin to bond to each other.

Walt Rosenthal's other interests included climbing and skiing. He soloed the classic Zodiac wall of El Capitan in Yosemite Valley and, during the early seventies, quietly ticked off a number of first ski descents. His adventures were pure and accomplished without any fanfare. Walt was modest and humble, extremely bright and engaging. He was great fun to be with.

Walt is survived by his wife, Lori, and 14-year-old daughter, Lilly. Memorial efforts, led by Mammoth Mountain Ski Area, have raised funds for the families.

— Daniel Dawson, Reserve Director
Valentine Eastern Sierra Reserve



CHARLES "WALTER" ROSENTHAL.
PHOTO BY JIM STIMSON

SAGEHEN CREEK FIELD STATION ORAL HISTORIES AVAILABLE ONLINE

UC's *Sagehen Creek Field Station at Fifty*, is a recently published volume of six oral histories that document the earliest days of the 452-acre NRS reserve located just east of the Sierra Nevada crest about 20 miles north of Lake Tahoe. This oral history compilation can now be accessed online at:

<<http://bancroft.berkeley.edu/ROHO/collections/pdfs/sagehen.pdf>>.

The interviews were conducted in 2004 by Historian of Science Sally Smith Hughes of the Regional Oral History Office at UC Berkeley's Bancroft Library. The six wildlife scientists interviewed — Glenn Flittner, Albert Jones, Richard Gard, Robert Behnke, David (and his wife, June) Taylor,



SAGEHEN BASIN IN WINTER. PHOTO BY JERRY BOOTH

and Don Erman — cover the research and experiences of key students, faculty, and staff who worked at Sagehen soon after its founding in 1951 by Starker Leopold (son of the eminent naturalist Aldo Leopold), who initiated the station's wildlife program, and Paul Robert "PR" Needham, who launched its fisheries program.

The Regional Oral History Office at UC Berkeley was established in 1954 to augment, through tape-recorded memoirs, the Bancroft Library's materials on the history of California and the West. — JB



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Recent *Transect* issues are also available for viewing on the World Wide Web at: <<http://nrs.ucop.edu>>. Subscription requests can be made via this NRS website.

DIRECTOR, NRS SYSTEMWIDE

ALEXANDER N. GLAZER*

PR. PUBLICATIONS COORDINATOR

SUSAN GEE RUMSEY

SR. SCIENCE WRITER

JERRY BOOTH

COPY EDITOR

LINDA JAY GELDENS

WEB MISTRESS

CAROLE GALASSI



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**Get well soon, Alex — we miss you!*

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Natural Reserve System

University of California

1111 Franklin Street, 6th Floor

Oakland, CA 94607-5200

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