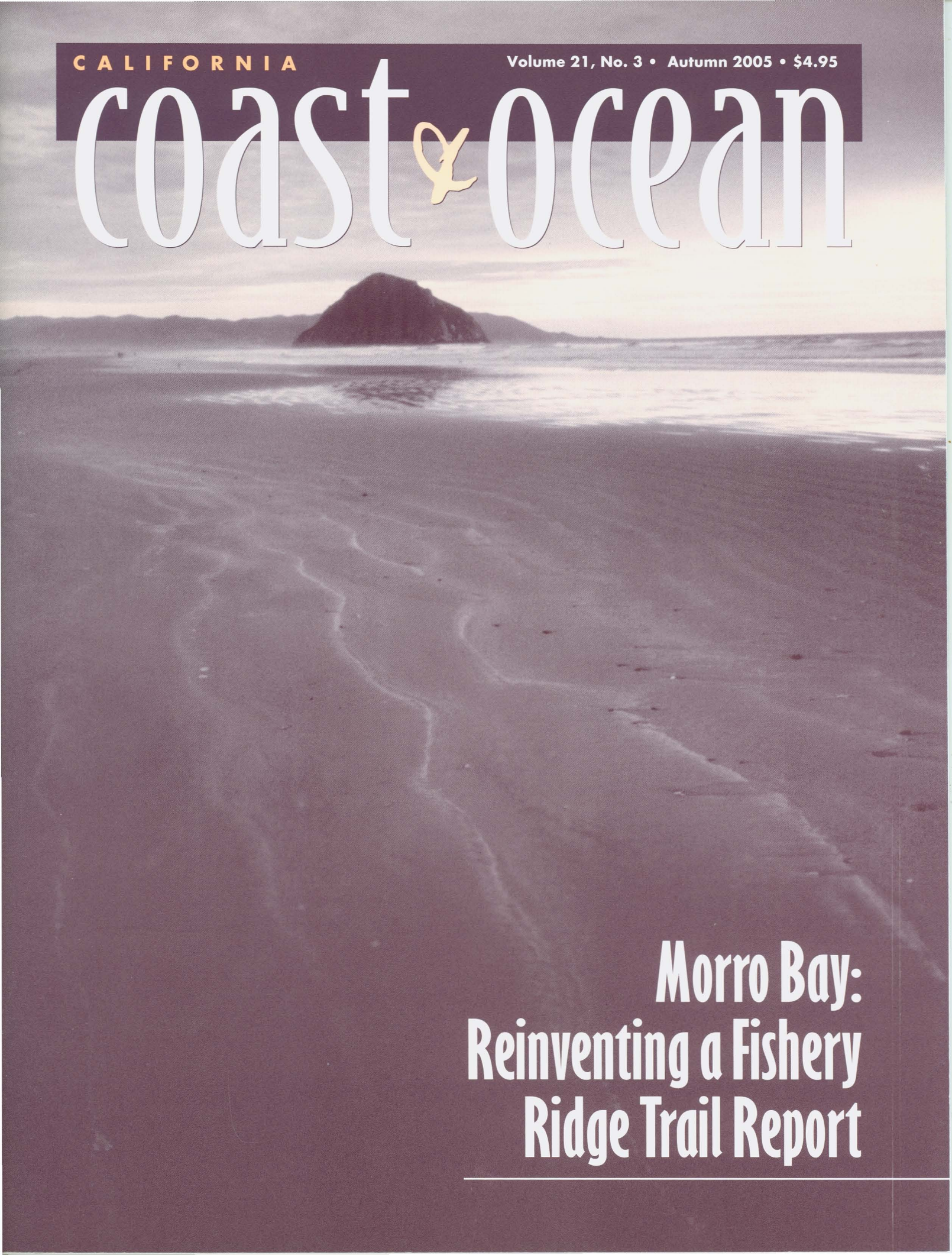
CALIFORNIA
coast & ocean
Volume 21, No. 3 • Autumn 2005 • $4.95



Morro Bay: Reinventing a Fishery

Ridge Trail Report

NEW C&O WEB SITE

The new *Coast & Ocean* web site is up and running at **www.coastandocean.org**. It will be under construction for a while as we add features and tweak the design.

Our web edition includes most articles from the current print edition (some abridged), some color images, back issues, and other information.

To subscribe to *California Coast & Ocean* for one year (four issues), $18 ($15 for teachers); for two years (eight issues), $33 ($30 for teachers), send a check payable to "Coastal Conservancy" to:

CALIFORNIA COAST & OCEAN
1330 Broadway, 11th Floor
Oakland, CA 94612

Subscriptions: (510) 286-0515;
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Editorial: (510) 286-0934;
editor@coastandocean.org

Cover photo: Morro Rock. Nature photographer, writer, and naturalist Susan Farrar travels to the Central Coast each fall to document the migration of shorebirds. Her passion is photographing northern California birds, wildflower meadows, wetlands, and forests.

Back cover: *Chromodoris michaeli* by Roger Steene

CALIFORNIA COAST & OCEAN

California Coast & Ocean is published by the Coastal Conservancy Association with a grant from the Coastal Conservancy.

The Coastal Conservancy is a state agency that works with the people of California to preserve, improve, and restore public access and natural resources along the coast and around San Francisco Bay.

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Prepress and printing: University of California Printing Services

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Articles appearing in *California Coast & Ocean* are indexed in *Environmental Periodicals Bibliography*, *Biology Digest*, and *Environment Abstracts*.

Printed on recycled paper with soy-based ink.

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SAVE THE DATE
for the California and the World Ocean '06 (CWO '06) conference: September 17–20, 2006, in Long Beach.

Ocean Love and Learning

MY SISTER AND I sat on the deck of our rented cabin above a wide sandy beach, ready for the sunset. Our eyes were on the glittering ocean, glasses of wine were in our hands, smoked peppered local salmon and smoked Pacific oysters from upcoast waited on the cedar table. (Yes, sorry, it's a classic fantasy. Bliss. It's almost embarrassing to mention. But in Oregon this experience is still available, at a reasonable price.)

The sun dropped into a low layer of fog without drama, but then a glorious afterglow spread across the sky.

I asked my sister what she felt when she looked at the ocean. She said it was the constant motion, constant change; rhythmic but not ever the same. A randomness, yet also a pattern. Peace, she said. Later I asked our landlady the same question. "Amazement, always," was her answer. "And the ocean is never the same, no matter how long you live beside it."

Yes, I thought, that kind of sums it up for me too, and probably for most of us. We are drawn to the ocean, it fills us with wonder and restores our spirits, as do forests and mountains and undisturbed meadows, as does wild nature in all its forms. Being land animals, though, most of us experience only the surface and edge of the ocean. And our inability to see what's going on in deep water is dangerous because by the time we become aware of extreme damage to ocean life, it may be too late to restore what's lost.

Fortunately, new tools are now available to expand our vision. In this issue, we report how advanced mapping technology is revealing the continuity of geological forms from the tops of watersheds to ocean depths. With this technology, the seafloor can be seen in detail and at landscape-sized scale. Bottom habitat can be mapped with new precision. (See "Ocean Floor Mapping," by Anne Canright, p.11; color images at www.coastandocean.org.) With such techniques, complemented by surveys using remotely operated vehicles and small manned submersibles (see "The Flight of the ROV," *Coast & Ocean*, Summer 2004), more and more of the California ocean is coming to public attention and eliciting concern.

Since our Minding the Oceans issue (Summer 2003), two national ocean commissions have published reports, more books and films with anguished messages and amazing images of undersea life have appeared, and more citizen activist groups have formed. As required by the California Ocean Protection Act of 2004, the California Ocean Protection Council has been established, funded with a fiscal year 2005–6 appropriation of $1.2 million, $10 million in tideland oil royalties, and a total of $15 million in Proposition 40 and 50 funds. (The Coastal Conservancy has agreed to commit $5 million to Ocean Protection Council priorities and the State Water Resources Board has committed $10 million.) The Council is coordinating the activities of ocean-related state agencies in an effort to improve the effectiveness of state efforts to protect ocean resources, and shaping new proposed ocean policies in keeping with Governor Arnold Schwarzenegger's Ocean Protection Plan, released in October 2004.

ASHOK KHOSLA

Among current Council projects are a pilot program to recover derelict fishing gear (see p. 17), kelp and eel grass restoration projects (*Coast & Ocean*, Spring/Summer 2005), and a proposed revolving loan fund to assist commercial fishermen trying to make a transition to sustainable fisheries in Morro Bay (see p. 33). Meanwhile, the Coastal Conservancy is implementing the Coastal Ocean Currents Monitoring Program (see *Coast & Ocean*, Winter 2004–5, and *www.cocmp.org*).

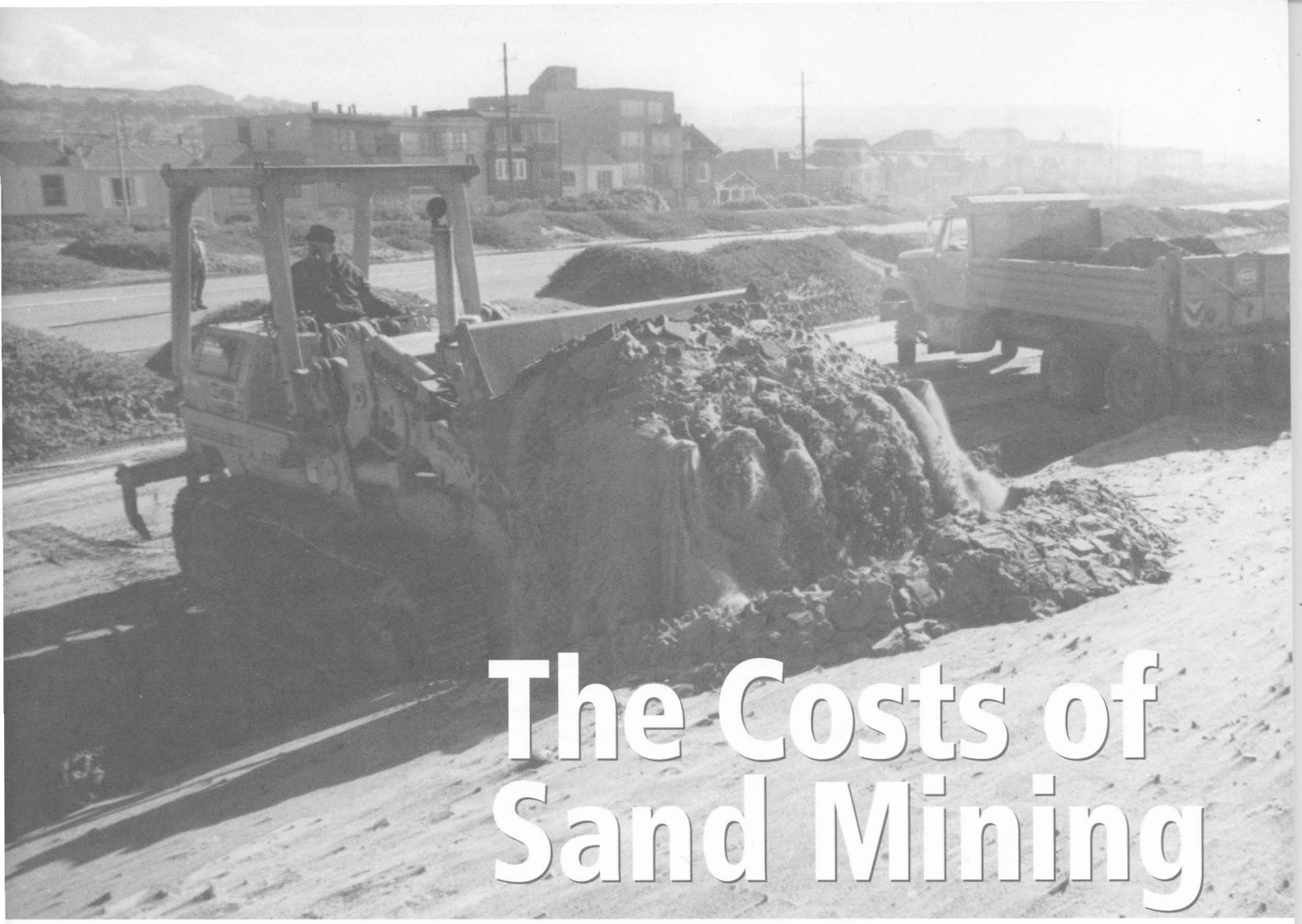
Recently, a videotape by the Algalita Foundation, "Our Synthetic Sea," inspired a conference on efforts to reduce the flow of plastics into the ocean. In the North Pacific Subtropical Gyre, midway between California and Hawaii, the volume of plastic microdebris now exceeds the volume of zooplankton by six to one. In our next issue we will bring you more on what is being done—or can be done—about this trash, which is killing seabirds and is now found in marine life at the cellular level.

In the often-quoted words of Senegalese ecologist Baba Dioum: "In the end we will conserve only what we love. We will love only what we understand. We will understand only what we are taught."

The morning after watching the sunset with the magic afterglow, I took a long solitary walk on the beach, crossing paths with only a few people, dogs, and an elegant raven. He was strolling along the surf line, inspecting the glistening sand with his beak as the tide receded. The sound of waves spending themselves gently on the sandy beach reminded me of the tamboura, the stringed instrument that, in classical Indian music, provides a background drone against which a sitar, tabla, or human voice can play, do acrobatics, sing passionately, and reach for the sky.

—*Rasa Gustaitis*

U.S. ARMY CORPS OF ENGINEERS



The Costs of Sand Mining

When Beaches Disappear, Who Benefits, Who Pays?

ORVILLE T. MAGOON
AND LINDA K. LENT

Sand removal at Ocean Beach, San Francisco, c.1980

As if the constant attack on coastlines by storms, waves, and currents were not doing damage enough, the "works of man" have greatly exacerbated coastal erosion, in both the short and the long term. And often the most damaging activities take place far from the ocean.

Our preliminary research, surprisingly, tells us that the primary cause of sediment removal from beaches is not dams but sand and gravel mining. Dams are the second major cause. Sand mining along the beaches of California and Oregon began in the late 1800s. Although it had been outlawed by 1991, substantial legal mining still goes on in coastal watersheds and even a stretch of coastal dunes near Monterey. Overall in northern California, from the Russian River to the Oregon border, some 11 million tons of sand and gravel are removed each year. That figure pales in comparison with southern California, where an annual average of 55.8 million tons is extracted, mostly around Los Angeles and San Diego, though wherever there is major construction of roads and buildings, there is usually a mine nearby.

All this extraction affects the shoreline. Even off-stream gravel mining is detrimental to beaches. Floodplain mining creates large pits next to dynamically changing river channels. If these pits are flooded during peak flows, they act as sinks for sediment. The normal transportation of sediment helps to dissipate a river system's energy. When sand and gravel are removed from within the channel, "hungry water," deprived of its natural sediment content, creates a disequilibrium that can cause erosion of gravel bars downstream.

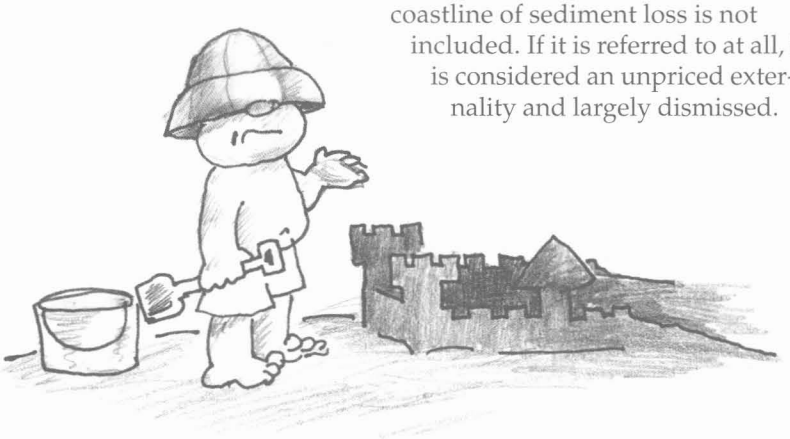
U.S. ARMY CORPS OF ENGINEERS

Sand mining at Sand City, just north of Monterey, c.1979

The second major cause of sediment removal is damming. More than 500 dams impound rivers and streams in California, affecting 38 percent of the coastal watershed (some 16,000 square miles). The dams reduce the average annual sand and gravel flow by 2.8 million cubic meters (enough to fill 1,000 Olympic-sized swimming pools) or 25 percent of normal, according to Cope Willis and Gary Griggs in the *Journal of Geology* (June 2004).

There are also a few minor culprits: "debris basins," built to trap sediments during floods; seawalls or coastal armoring, which can have major local impacts; dredged navigation channels, where material is taken offshore out of the nearby littoral system, as happens in Humboldt Bay and the Columbia River estuary; and subsidence, both natural and human-induced.

Whenever sand or gravel is removed from the ecosystem, a cost, often a substantial one, is incurred downstream. Yet in project cost estimates for commercial shipping, building dams to provide water and power, or mining for construction, the cost to the coastline of sediment loss is not included. If it is referred to at all, it is considered an unpriced externality and largely dismissed.



ALL DRAWINGS BY MARCIA GRIMM

We have attempted to calculate the amount of sand and gravel lost to the beaches and to estimate the actual cost of those externalities, for they are only "external" to those doing the extracting. To ignore them is poor accounting as far as society as a whole is concerned. To those who live along the coast or enjoy the shore, their loss is of major consequence.

Before introducing dollar amounts, we should explain that we have little confidence in the accuracy of the figures we discuss, which are estimates compiled or extrapolated from multiple secondary sources. Nevertheless, these numbers, however inexact, are not without value, for they allow us to understand the rough impact of this extractive industry. Until now, no statistics have been brought together to suggest the true extent of sand and gravel mining in the western states.

Even more important, these numbers highlight an important principle. If we as a society choose to tacitly accept the underpricing of certain endeavors by ignoring the negative "downstream" consequences, we should also bear the cost of compensating those who suffer losses. Yet as public monies available for that purpose become increasingly scarce, more and more often the damage goes unrepaired. In the meantime, the costs—in this case to beach communities—mount, while those who profit from the mining or dam building incur no costs from using up the natural resource, and therefore have no incentive to avoid sediment losses to the shoreline.

Three Ways to Figure Losses

THE ECONOMIC IMPACT of sediment losses can be estimated in three ways: in terms of replacement cost, remediation cost (which attempts to compensate for past and future damages), and repair cost (or "fixing" the shoreline to protect against future damage).

The replacement cost of lost sediment (see p. 6) is based on a generic estimate of $12 per cubic meter. (The Port of Long Beach, which has undergone serious subsidence that must be rectified—at a potential cost of $500 million to $1 billion—is excluded from this estimate). The cumulative sediment loss in California so far is estimated at 1.4 billion cubic meters. The cost to mitigate that loss by beach nourishment is estimated at $16.4 billion. Each year there is a further sediment

loss of 29 million cubic meters, a loss that would cost $333 million to mitigate. In the unlikely event that any sizeable effort should be mounted to replace the sediment, the actual cost would be much higher, driven up by the tremendous demand.

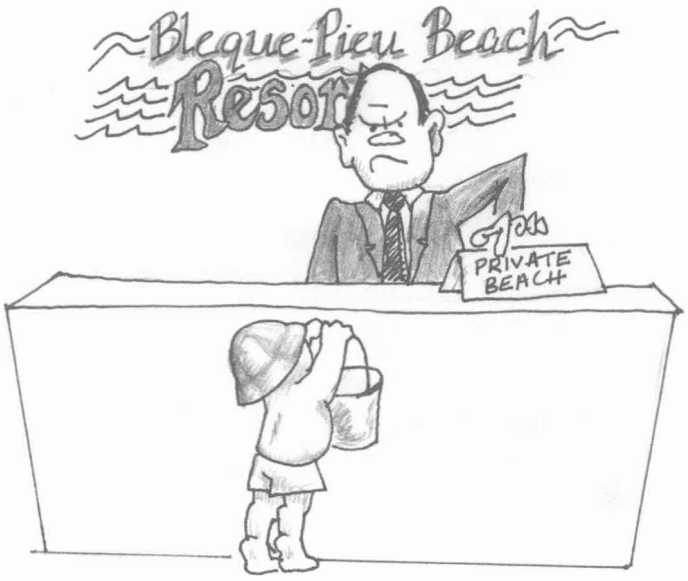
There is also a cascade of consequences, both initially negative and positive and not easily quantifiable, to coastal and riverside resources and communities. Loss of both structures and beach sand are two outcomes of sediment removal from streams, each with economic consequences. Researchers at the John Heinz Center for Science, Economics, and the Environment in Washington, D.C., estimated that of 4,600 structures within 500 feet of the shore, five to ten percent are likely to suffer damage from erosion sometime during the next 60 years, with an average annual expected loss of $110 million.

The loss in structures can be added to the estimated loss in recreation values. If those who have removed sediment or prevented it from reaching the shoreline had to pay for remediation, the bill would be about $2.7 billion.

The U.S. Army Corps of Engineers has undertaken five beach nourishment projects along the California coast since 1959, putting back about 56 million cubic yards at a cost of $258 million. The state of California has compiled a "wish list" of projects to repair small sections of the shoreline that are already in perilous condition. The estimated initial cost is $120 million.

Who should pay? In the case of oil spills, the Oil Pollution Act of 1990, passed after the Exxon Valdez oil spill, states that "the polluter pays." This principle was upheld by the courts in several cases stemming from a huge oil spill in 1990 from the tanker *American Trader,* which ran aground on one of its anchors off Huntington Beach. Shouldn't the remover of sediment that results in economic harm also be held economically responsible for losses incurred, both actually and potentially? To be sure, while it is usually possible—though not always easy—to identify the source of an oil spill, it is far more difficult to show convincingly who is responsible for the absence of sand on the beach, especially when there could be—and often are—several culprits. However, there are precedents with settling water rights where the various extractors are assessed responsibility.

In the case of sand mining, if the construction industry were to pay for all reasonable mitigation and replenishment, the cost would almost certainly be passed on by raising the price of concrete. We estimate that it would rise by $2.22 per metric ton, on average, or 31 percent. That money would then be paid to an agency to buy sand, or for appropriate compensation. Concrete products, already the highest-priced product made from sand, would increase 15 percent, while fill, the use with the lowest price, would increase 39 percent.

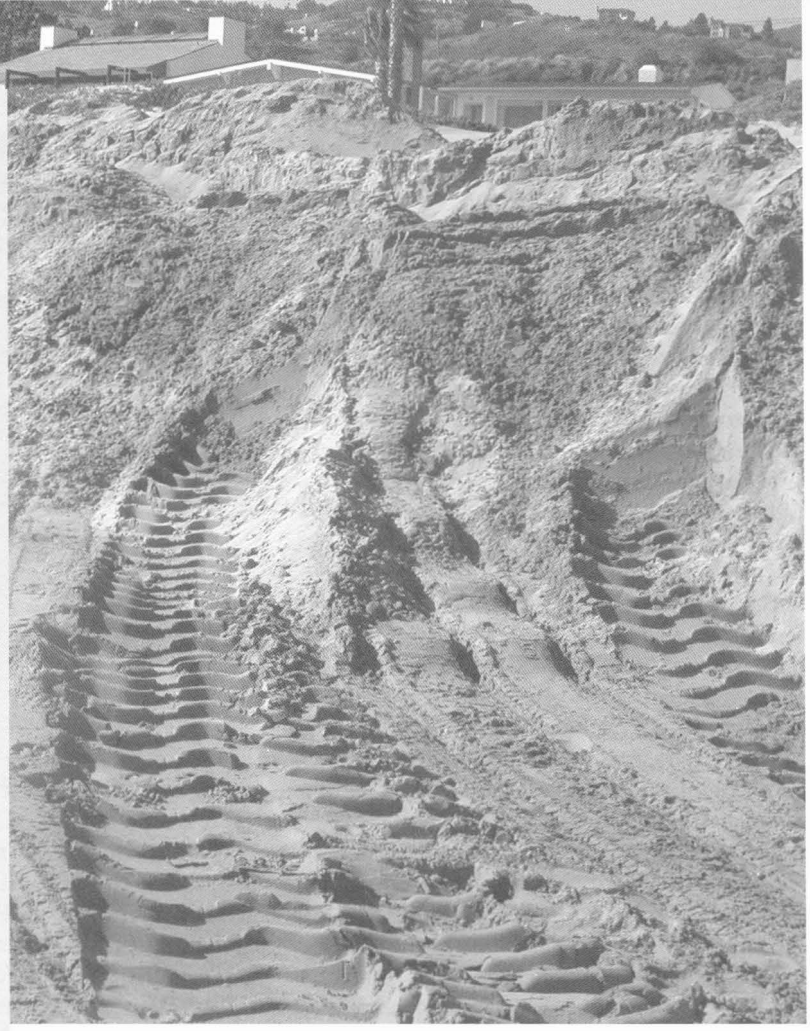


At $12 per cubic meter, the 4.8 million cubic meters of material lost each year behind dams costs $57.6 million. For projects primarily built for flood control, those who benefit from the dam—utility companies, farmers, etc.—could be allocated the cost of the loss to the shoreline. Where a dam is built for power generation, the unit cost of the power could be increased to reflect the lost sediment. And for all dams that act as reservoirs for water use, the mitigation costs could be added to water bills.

WHAT'S THE BEACH WORTH IN DOLLARS?

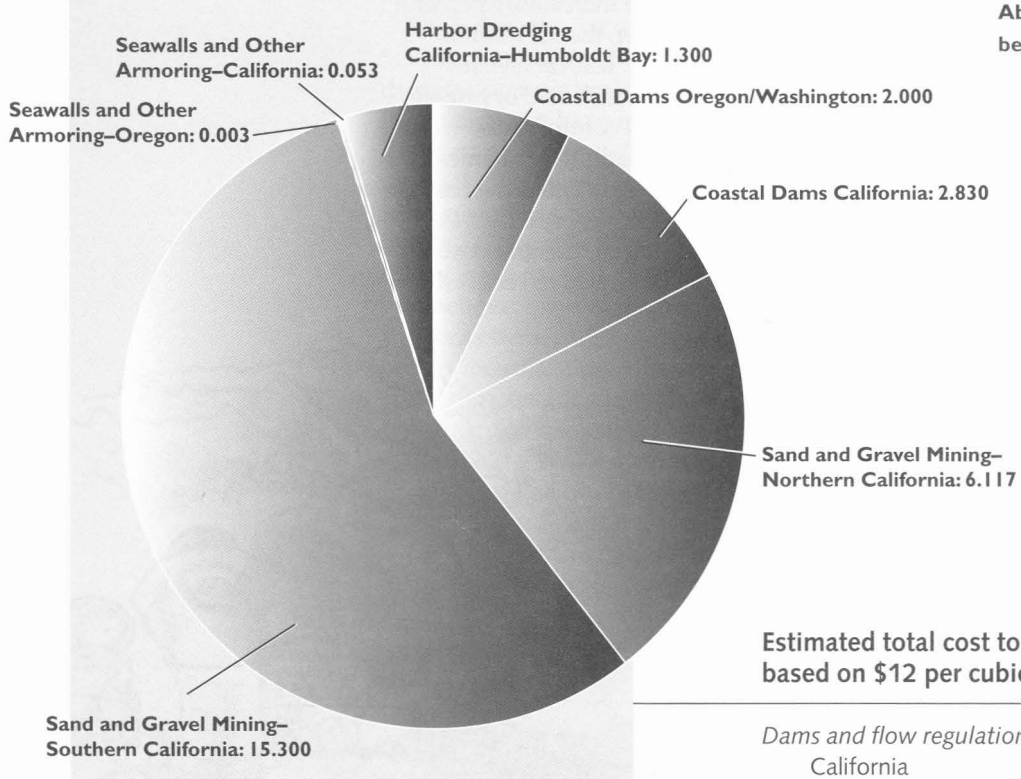
SEVERAL ATTEMPTS have been made during the past decade to place a dollar value on healthy California beaches and to gauge the economic impacts of their loss. An analysis prepared for the Department of Boating and Waterways by Philip King and Douglas Symes in 2003 found that if California beach users were to abandon California beaches for beaches out of state, the Gross State Product would shrink by $5.5 billion a year and the direct loss to the State in taxes would be $509 million. Earlier studies by King and Michael Potepan found that beach-related spending supports over half a million jobs, and that in 1995, residents and visitors together contributed $10.6 million directly to the state economy. Visits to California beaches totaled more than 565 million that year. Since then there has been an increase in beach visits, beach-related jobs, and the dollar value of beaches to the state and to coastal communities.

—Lesley Ewing



CALIFORNIA COASTAL COMMISSION

Above: Earthmover tracks lead to an illegal berm on Broad Beach, Malibu (see p. 8).



Annual sediment losses, U.S. Pacific Coast, in millions of cubic meters

Estimated total cost to date of coastal sediment loss, based on $12 per cubic meter.

Dams and flow regulation	
California	$1.4 billion
Oregon/Washington	$1.3 billion
Land-based sand & gravel mining	
Northern California	$3.9 billion
Southern California	$9.7 billion

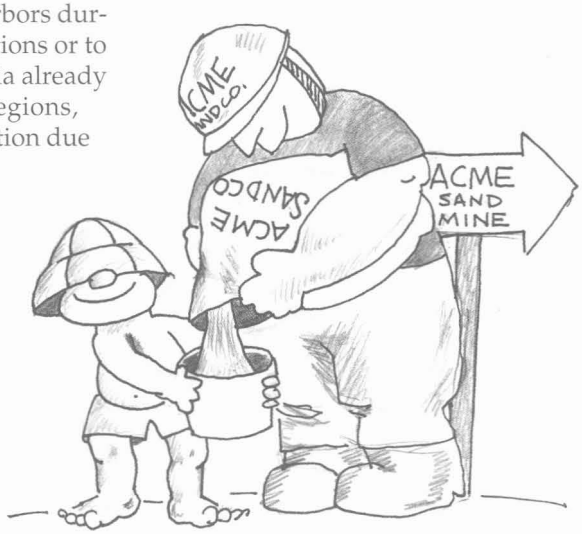
Alternatives to Mining

RATHER THAN INCUR these costs, a far more attractive alternative for industry would be to explore more aggressively the alternatives to mining virgin aggregate.

One option, already widely used in the United States and elsewhere, is to use recycled concrete products rather than "virgin" sand and gravel in the foundations of buildings and roads. The many benefits include improved performance—in greater strength and durability, control over gradation, and the potential to minimize cracking; and reduced environmental impacts—less disposal and dumping, fewer unsightly piles of concrete rubble blighting the landscape, and of course more virgin aggregate available for projects that really need it. Economic benefits include shorter hauling distances of material that would otherwise be considered waste, and general cost savings through the use of less virgin aggregate.

Another option for reducing sand and gravel mining in California is to import from other regions and countries and to reduce the export of California-mined aggregate. Currently, the United States annually imports 3.8 million metric tons of sand and gravel at an average cost of $12.51 per metric ton—higher than the estimated $12 per metric ton cost of domestic sand and gravel. The vast majority comes from Canada, from inland glacial deposits where mining does not directly impact the coast. California imported about 2.2 million metric tons of sand and gravel during 2002, compared with 816,000 metric tons in 2001. Imports to the San Francisco Bay Area are expected to increase significantly during the next few years because of the recent closure of the Hanson Aggregates' Radum Plant, a major local mine.

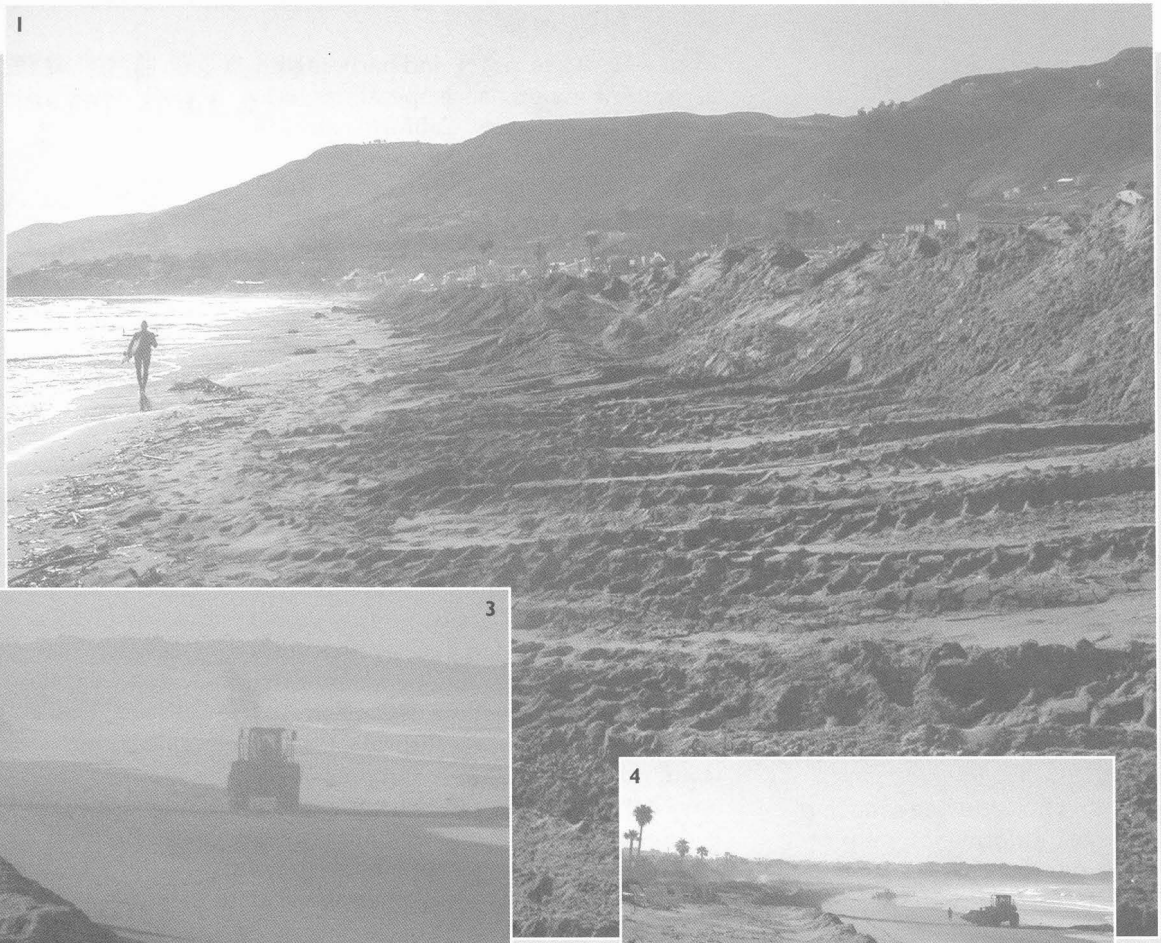
Meanwhile, exports of sand and gravel from the United States in 2002 totaled 2.6 million metric tons of sand and 600 thousand metric tons of gravel, most of it from California. Reductions in exports may not be feasible in light of the high quality of material from the United States, which has the most advanced equipment for grading sand in huge quantities. Sand and gravel mined and processed in the United States can therefore be used for virtually any application. A third option is to replace the sediment lost to the shoreline from sand and gravel mining with material dredged from waterways, ports, and harbors during routine maintenance operations or to deepen ship channels. California already follows this practice in most regions, Humboldt Bay being the exception due to pressure from fishermen wanting to preserve the seabed intact. Sand can also be moved from offshore into the nearshore system, as sometimes is done for beach nourishment.



Sand and gravel mining is not going to stop, and although very few dams were built in the last 20 years, there is continual pressure to build more. Neither industry is likely to offer compensation voluntarily for removing beach material. Meanwhile, the coastline of California, particularly southern California, is in constant threat from erosion. If there is to be any change in the regulations governing beach deprivation, and sand and gravel mining in particular, those who are paying the price must become much more vocal in their protests. ■

Orville T. Magoon, president of the Coastal Zone Foundation, has more than 35 years of experience with the U.S. Army Corps of Engineers in coastal zone management, coastal structures, and their rehabilitation.

Linda K. Lent, who runs a consulting company based in Bethesda, Maryland, has been evaluating the economics of shoreline and other water resource issues for 25 years.



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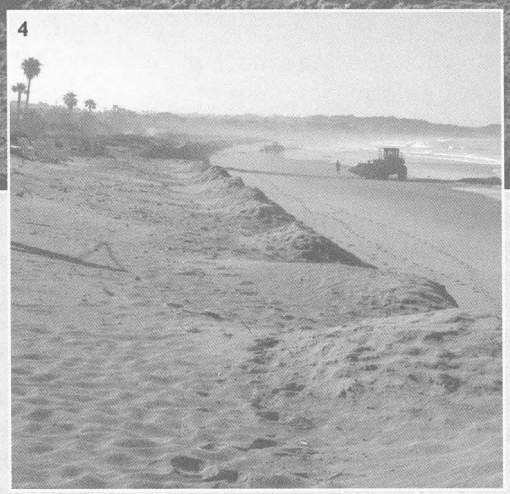
Malibu Sand Heist

WHAT HAPPENED TO BROAD BEACH?

IN JUNE, FRONTLOADERS scooped sand from the public tidelands to build a berm in front of homes. On June 7, an outraged citizen phoned the Coastal Commission, and staff from the Ventura office rushed to the scene. It was after 5 p.m. by the time they arrived and the workers had quit for the day. Much of the berm had already been built (1 and 2). At 7 a.m. the next day, Commission staff returned. The beach excavation resumed (3 and 4), but when the frontloader's operator was asked to stop, he did.

On June 16, the Commission's executive officer issued a cease and desist order to the Trancas Property Owners Association requiring that the sand be put back and the beach profile be repaired before July 4. The Association complied. Kenneth A. Ehrlich, attorney for the Association, said "the property owners were surprised at the work that was done." Their intent had been to repair and restore the dunes on the beach with sand from private beach property, he said. In August, the Coastal Commission and the State Lands Commission filed suit against the Association for fines and penalties for removing sand from state property without a permit, a month-long loss of public access (the public was left walking in water as a result of the sand removal), and loss of grunion eggs that had been laid on the upper beach and buried during the week the berm was being built. As part of a separate action, the "Private Property" sign in photo 2 was found to be illegal, and has been removed.



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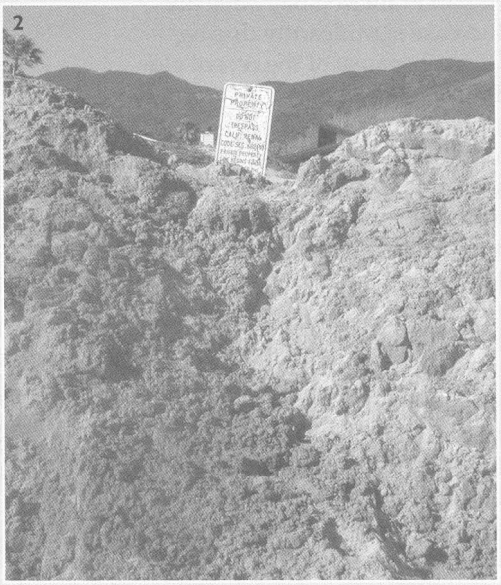

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PHOTOS THIS PAGE: CALIFORNIA COASTAL COMMISSION

Scooping up grunion eggs for lab study

Grunion in San Francisco Bay

BILL O'BRIEN

PHOTOGRAPHS BY MALCOLM LUBLINER

WE MET JUST BEFORE one a.m. on a cool, misty night in early June. The moon was new; Crown Beach in Alameda was dark and deserted. There were four of us—Jody Zaitlin, Terry Coddington, photographer Malcolm Lubliner, and myself. As the tide began to recede, we set out, aiming our flashlights into the small waves that brushed the shoreline. We were hoping to see the spawning ritual of the California grunion, the only fish known to leave the ocean to lay its eggs. We were also trying to help answer a question: Do *Leuresthes tenuis* live and reproduce in San Francisco Bay, or are they simply visitors who ride in on a warm current, then leave at the first opportunity?

In southern California, dozens—even hundreds—of folks will gather on sandy beaches to watch a "grunion run." Between Point Conception and Baja California, these small, silvery fish emerge from the water by the thousands during the highest spring and summer tides. The females, five to six inches long, wriggle out onto the sand and use their tails to dig shallow holes, in which they lay their eggs. The males then snuggle up next to the females and deposit their milt, or sperm, onto the eggs. Then everybody flops back to the water, catches a wave, and heads back out to sea.

It's quite a spectacle. Grunion runs are predictable. The California Department of Fish and Game publishes a timetable, and organizations including the Cabrillo Marine Aquarium organize public tours to the scenes of the action. The Grunion Greeters, a citizen scientist brigade coordinated by Karen Martin, a biology professor at Pepperdine University, goes out and takes notes on the spawning activities. The project was started three years ago and now has about 500 members, mostly in the Los Angeles area.

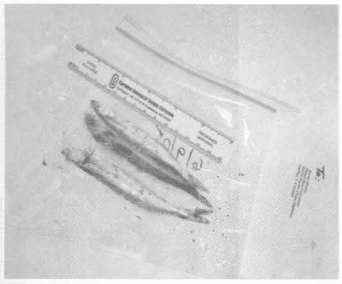
On this June night in Alameda, however, the four of us had the whole beach to ourselves, and for a while it seemed that our solitude would remain undisturbed, even by grunion. We were hopeful, however. Zaitlin, an associate environmental planner with the Port of Oakland, and Coddington, a newly trained volunteer Grunion Greeter, had seen some grunion under the recent full moon, and we were eager to find out if there would be a repeat performance tonight, with the new moon. Our hopes were soon realized—sort of.

Coddington spotted the first grunion after we had walked along the beach for about ten minutes. Soon we all had sightings, eight to ten fish at a time, silver ripples appearing suddenly at the water's edge. Their movements were so quick that we couldn't tell if they had actually emerged from the water or not. We kept walking for about half a mile and spotted maybe a hundred fish altogether.

The mist grew heavier and the air colder, and the silvery ripples became scarcer and scarcer. Our foursome hung in for a while, but no more fish appeared. Zaitlin and Coddington sat down on a log to make a few notes, then we all headed for our cars and the warmth of home, leaving the beach deserted—at least until the next high-tide night.

IN MALIBU, three grunion runs were damaged last summer when property owners built an unpermitted berm on Broad Beach with sand scooped from the public beach (see p. 8).

One run's eggs were buried by earthmoving equipment, a second run was unable to spawn because the sand needed had been displaced, but the third run, though smaller than expected, was partially saved by Karen Martin and students. To prevent eggs from being disturbed as the property owners' association obeyed the Coastal Commission's order to restore the beach, the eggs were collected. When the tiny fish hatched, they were released.



Karen Martin took samples of grunion and eggs to study in her lab.

Until 2001, the only reliable report of grunion in San Francisco Bay was 150 years old. Since 1855, the farthest north they had been reported spawning was Monterey Bay. Four years ago, however, six were taken by trawlers during regular monitoring programs. Since then the numbers have steadily increased, according to Kathy Kieb, associate marine biologist at Fish and Game. Grunion also turned up in surveys of fish dropped by least terns at their nesting site on the former Alameda Naval Air Station, and some were caught by biologists from the Port of Oakland. In 2004, trawlers netted 141 grunion in the Bay.

Last year Andy Jahn, a marine scientist with the Port of Oakland, got a "strong indication" that grunion were breeding here: during a spring fish count, one began laying eggs in his hand. For him, "the only question at that point was 'Where do they spawn?'"

Jahn mentioned the Bay grunion during a lecture he gave in May 2004 at the Southern California Academy of Sciences. Karen Martin, who has been studying grunion for a decade, was among those in attendance and was intrigued. A late-season visit to the Bay failed to reveal any grunion, but she began making plans for a more extensive study in 2005. Aided by the Port's Zaitlin, she set up a workshop for people interested in becoming Grunion Greeters, to show them what to look for and how to record their findings.

Crown Beach, with its long, sandy shoreline and relatively warm water, seemed promising. Greeters went out for three nights during the full and new moons of June, and indeed saw spawning. Martin then visited the beach during daylight hours and found several clutches of the tiny, greenish-orange eggs buried several inches deep in the sand. She took them to her lab, where they hatched and she observed larvae emerging.

So grunion were, indeed, reproducing in the Bay. But now new questions arose: Are they new arrivals, or have they been in the Bay, undetected, all along? Might they have been separated from their southern relatives long ago and evolved into a separate population, or even a new species of grunion?

Hieb and Jahn doubt they have been present for long. Had they been here in significant numbers, they figure, monitoring programs would have picked them up long before 2001. Yet it is only during the past two years that some have been caught regularly, almost every month, in both central and south San Francisco Bay. Hieb speculates that these little fish may have come in as a result of the Pacific Decadal Oscillation, the regular warming and cooling trend in the Pacific.

Martin, however, suspects that the San Francisco Bay grunion may have been in the Bay for a while, and may have been separated from their southern relatives long enough to have evolved into a new species. Their eggs are considerably smaller and somewhat paler than those found farther south, she notes, and adult fish are an inch or so shorter. Their spawning behavior is also different. In southern California, grunion ride the waves far up onto the sand, and remain on land for up to a minute. On Crown Beach, where waves are tiny, they don't come out of the water for more than a couple of seconds, if at all. This behavioral change would have taken generations to develop, according to Martin.

Trawlers could have missed seeing the fish, if their numbers were small, because "grunion are very cryptic (well camouflaged)," Martin said. "They're hard to find even if you know they're out there." Perhaps the local population increased in recent years because of warmer Bay water or other factors, she said. A genetic analysis of the new-found grunion, which she plans to undertake, should help to answer some of these questions. It is expected to take about a year, and local marine researchers are eagerly awaiting the results. "It's a nice little mystery right now," said Jahn.

Throughout the rest of June, during the full and new moons of July, and into August, Grunion Greeters searched Crown Beach. According to Martin, grunion numbers peaked in July, though Greeters saw some spawners on every visit. Meanwhile, the mystery grew—in July grunion were discovered spawning even farther to the north, in Marin County's Tomales Bay. Martin hopes to do follow-up work there next season. ■

Bill O'Brien, an independent reporter based in Oakland, last wrote for Coast & Ocean *about school gardens.*

Ocean Floor Mapping

ANNE CANRIGHT

I AM LOOKING AT a map. It is large, several feet by several feet, and hangs on the wall of the office of Rikk Kvitek, a professor of science and environmental policy at Cal State University Monterey Bay and director of CSUMB's Seafloor Mapping Laboratory. Vibrantly hued, the map depicts Elkhorn Slough, a vital 70-square-mile wetland and watershed on the central coast. The colors represent various land uses and habitat types—natural oak woodland, acres of pickleweed, ranchland, agricultural fields, the built-up areas of Moss Landing at the slough's mouth, the Duke Energy power plant. The depiction is more or less realistic: you can almost see the dips of land into shaded valleys; the rise into pine groves where, each spring, great egrets and blue herons raucously nest.

More remarkable than the depiction of the land, however, is what the map shows of water features: the main channel and dendritic fingers of the slough itself, the basin of Moss Landing harbor, the nearshore waters that, for the most part, gently slope away from the land—but then there's the slash of the Monterey Submarine Canyon, wending its way quickly to great depths.

These features don't show up as the plain blue of most maps—the water as seen from land, a flat surface that hides whatever smooth, bumpy, or convoluted surfaces might lie beneath. Instead, the subsurface

CSUMB SEAFLOOR MAPPING LAB

Detail of a very high-resolution digital elevation model of Elkhorn Slough, Monterey County. This combines ship-based sonar bathymetry and airborne lidar bathymetry to create a map accurate to one meter. (See color images at www.coastandocean.org)

COURTESY JAMES FORD BELL LIBRARY, U. OF MINNESOTA

Detail of a portolan chart by Albino de Canepa of Genoa, 1489, showing the eastern Mediterranean and the Black Sea

land—the muddy bottom, sandy seafloor, rocky reefs—is depicted in all its glory. Although it's covered with water, the land down there is just as rich and interesting as the land up here.

And now we have the technology to depict it. It is as if a set of golden gates has been unlocked and swung open, allowing access to a realm hitherto accessible only in bits and pieces to a select few who made the extra effort, with plumb lines, wetsuits, and active imaginations.

Imaging the Oceans

FOR MILLENNIA humans have enjoyed a love affair with the ocean. We have gazed out at the ocean's ever-changing light and dreamt of distant lands; gained comfort from the regularity of flowing and ebbing tides and the ever-present waves; found sustenance in the bounty of the marine realm. One could argue it's a somewhat superficial love affair, concentrating on the rolling surface waters and going only so deep—but it has shaped who we are.

Sailing across vast distances, we have learned how to use forward-propelling tailwinds, to catch pelagic sailfish and tuna, to survive hurricanes at sea. From the surfline, from piers, from small boats near to shore, we have lowered hooks and nets, traps and trawls, to garner delicious fishes for our tables. There was also the occasional "monster," which came from who knew where, to provide a chill or thrill—ineffable, feared, but more or less harmless so long as we stayed on land, or near it.

With increasing familiarity, as well as practical need, came the desire to portray the oceans' surface in a scientific manner: with maps. "Scientific" does not necessarily mean high-tech. The Marshall Islanders have for generations made navigational "stick charts" of palm-leaf ribs, fiber cord, cowrie shells, and coral. One type, the *rebbelib*, shows with astonishing accuracy the patterns of wind-generated swells and waves over an area roughly 600 miles square. The larger-scale *mattang*—depicting a single island or small group rather than an entire island constellation—is more generalized, used for training purposes.

In Europe, a navigational map that combined expediency and conscious beauty came into being around 1300: the portolan chart. Here, shorelines are emphasized, while terrestrial information is played down. Place names fringe the coasts, and lines designating wind bearings crisscross the seas: black for the eight principal winds, green for the eight half winds, and red for the sixteen quarter winds. With compass roses, coats of arms, flags, and miniature representations of cities added, painted in gold, silver, and rich reds, greens, and blues, these maps became works of art rather than mere navigation aids.

Over time, cartographers began looking beneath the surface and plumbing—literally, with "casts of the lead"—the oceans' depths. Knowledge of undersea obstacles as well as of coastline features grew increasingly important as the maritime powers swept throughout the world in their colonizing enterprise, battling each other along the way. By the 19th century all the great modern governmental hydrographic offices had been established, and navigational charts, bathymetric maps, and a variety of special-purpose oceanic maps were pouring from their presses.

Today, commercial shippers as well as recreational boaters rely on nautical charts, which now come in traditional paper and downloadable versions. In the United States, they are produced by the Office of Coast Survey, within the National Oceanographic and Atmospheric Administration. You've probably seen one: they show the land as butter yellow, and prominent coastal features are recorded for purposes of triangulating one's position at sea. The water is a pale sky blue, with various point and line information overprinted: bathymetry (lines indicating bottom depth, the equivalent of contour lines on a U.S. Geological Survey topographic quadrangle), underwater obstructions such as rocky spires or shipwrecks, the location of fixed navigation buoys. In concept, these charts are rather like the portolan charts of the 13th century, downplaying the land, highlighting the sea.

For boaters, these maps are very useful—life-savingly so, on occasion. But boaters' interests still rest more or less on that surface realm of the water. They need to know what's beneath them so they don't hit it, but they don't need a lot of detail besides. A blue and yellow map with a smattering of line and point symbols serves their purposes just fine.

Going below the Surface

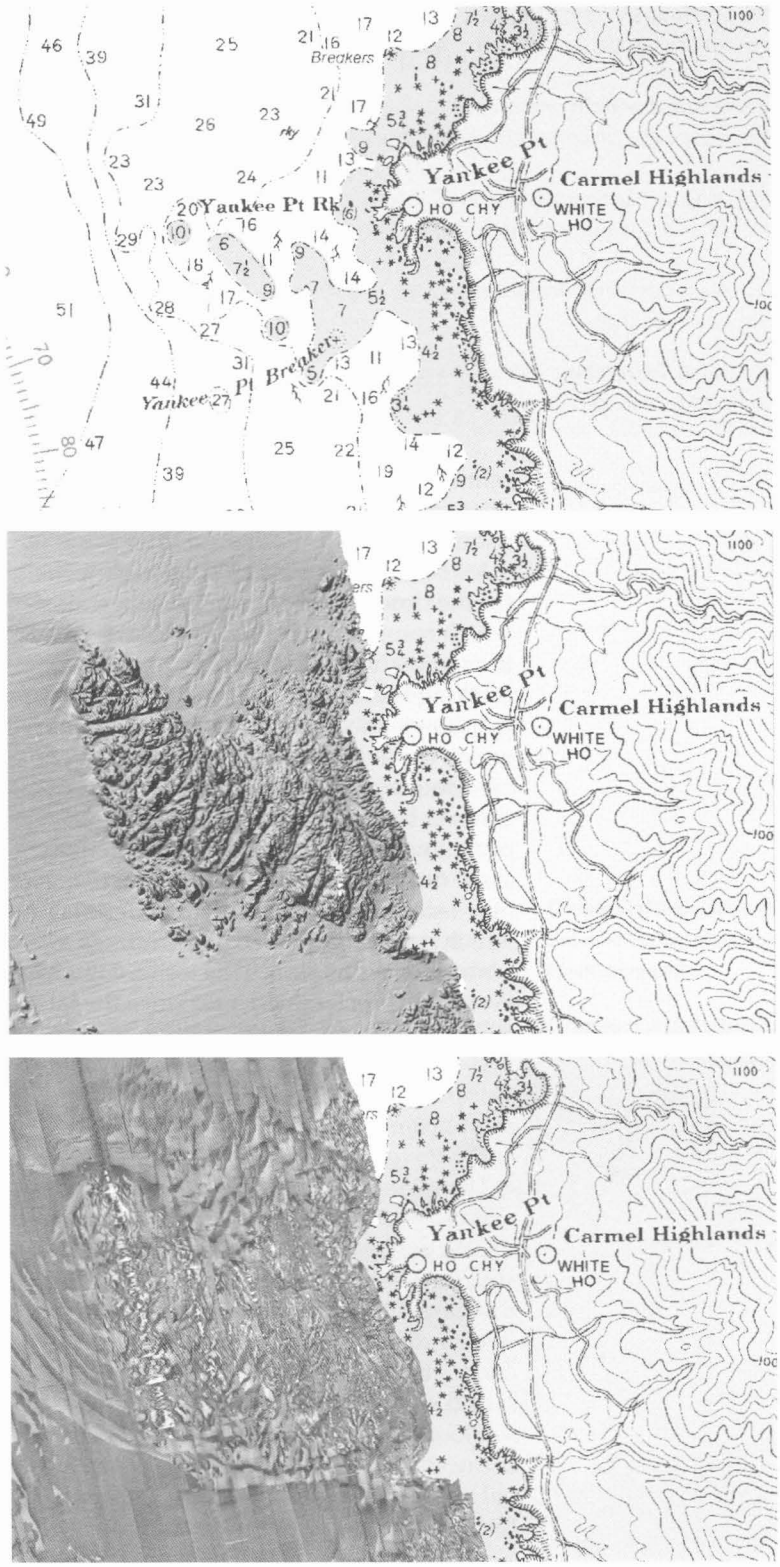
OUR ABILITY TO visualize the undersea realm began to change around the time of World War I, when underwater sound projectors—sonar (short for "sound navi-

gation and ranging")—came to be used for submarine detection. By the 1920s, the Coast and Geodetic Survey (forerunner of the Office of Coast Survey) had adopted this technology to map deep water. Some of the first detailed maps of the ocean floor were produced in 1939 on the East Coast by the team of A. C. Veatch and P. A. Smith, whose work demonstrated that offshore canyons extended into very deep water. Advances in sonar and electronics during World War II led to improved data collection systems. Precisely timed measurements of sonar signals allowed the representation of deep-sea trenches and midoceanic ridges, based on hundreds of thousands of soundings at hand-picked depths. The 1957 publication of Bruce Heezen and Marie Tharp's *Physiographic Map of the North Atlantic* (followed by maps of the South Atlantic, the Indian Ocean, and ultimately all the seas) enabled lay map readers for the first time to visualize what the ocean floor looked like. It also helped fuel the plate tectonics revolution of the 1960s. Our world was growing larger and smaller—or at least, better understood—at once.

I recall the first time I ever saw a map of the seafloor—it was, I believe, the 1974 Heezen-Tharp *World Ocean Floor Panorama*, and it was a revelation. It made the land and the watery subsurface seem on a par, equally important. I was already familiar with color-enhanced shaded-relief maps of the world's land surface (*National Geographic* inserts, no doubt) and had long enjoyed imagining tramping in the Rocky Mountains (represented in browns and whites), or whacking back the lush growth of a Burmese jungle (deep blue-greens), or combing a Caribbean beach (yellows and creams) for pirate booty. But when I saw the same plateaus, volcanoes, ridges, peaks, and canyons punctuating the bottom of the sea, my world suddenly doubled in size. (Well, to be precise, it more than tripled.) Although I couldn't imagine myself ever standing on a midoceanic ridge, I was somehow comforted to know that the seafloor was just as three-dimensional as my own terrestrial backyard. Occasionally a story about Jacques Cousteau or William Beebe would catch my attention, and my somewhat medieval take on the oceans as being full of sea dragons and tentacled monsters bit by bit reshaped itself along more realistic lines. It has been expanding ever since, as has the technology that allows us to see the seafloor.

Unfortunately, we can't just go out and take pictures of the ocean bottom as we can dry land, where aerial photography and remote sensing imagery from satellites have revolutionized our understanding of the earth's surface above mean sea level. In the ocean, light penetrates only to a few hundred feet, and it is difficult (with cur-

Three ways of mapping the seafloor off Yankee Point, Big Sur: Top, a NOAA navigation chart; center, multibeam bathymetry 3D shaded relief model; bottom, side-scan sonar 2D backscatter imagery



IMAGES THIS PAGE: CSUMB SEAFLOOR MAPPING LAB

MANY WEB SITES have ocean floor maps of various kinds. Others have excellent collections of historical ocean maps and navigational charts. Check these out.

The CSUMB Seafloor Mapping Lab:
http://seafloor.csumb.edu

Moss Landing Marine Labs Geological Oceanography:
http://geooce.mlml.calstate.edu

USGS Pacific Seafloor Mapping Images:
http://walrus.wr.usgs.gov/pacmaps/site.html

USGS San Francisco Bay Bathymetry:
http://sfbay.wr.usgs.gov/access/Bathy/zTool.html

NOAA Office of Coast Survey Historical Map and Chart Collection:
http://nauticalcharts.noaa.gov/csdl/ctp/abstract.htm

James Ford Bell Library Historical Maps:
http://bell.lib.umn.edu/hist

Zoomable National Geographic Ocean Floor Maps:
http://www.ngmapstore.com

rent technology) to take useable seafloor photographs from depths greater than about 35 feet.

Mid-20th-century mapping, high-tech for the time, relied on single-beam sonar, which resulted in limited soundings, read immediately below the ship along a single tracking line from the ship itself. The information gleaned was precise depths, from which the shape of the seafloor could be laboriously pieced together by means of contour lines—a process aided by computer automation since the 1960s. In that same decade, the U.S. Navy began using a new technology called multibeam sonar, which produced swaths of soundings to both sides of the ship. This technology was eventually declassified, and since the late 1970s the scientific community has continued to improve on its capabilities. Modern mapping systems combine sophisticated multibeam sonar, computer algorithms, and GPS (geographic positioning systems).

The related technology of sidescan sonar makes possible detection not only of ocean depth, but also of topography and type of substrate—rocky, sandy, silty, sludgy. In this case, the sensing instrument, towed underneath the ship on a long electrically conducting cable, sends and receives sound signals over a broad swath of the seafloor. Depending on the hardness or softness of the substrate, the returned signal will be stronger or weaker. A trained technician can key out these materials with considerable accuracy. This type of survey can cover an area up to several hundred kilometers wide.

A relatively recent technique in the mapping toolkit brings us a step or two closer to underwater photography, at least in nearshore areas—and it does so by taking to the air. Airborne lidar bathymetry (where lidar stands for "light detection and ranging"), which works something like radar but substitutes laser pulses for radar's microwaves, is faster, more accurate, and cheaper than traditional boat-based mapping. Its usefulness, however, is limited to waters that are clear, calm, and shallow. With the array of techniques now available, virtually any sea bottom we might want to map is there for the imaging (unless it's inconveniently, and more or less permanently, covered by ice, of course). All it takes is a little cold, hard cash.

More Than a Map

ALTHOUGH THE ELKHORN Slough map I admired in Rikk Kvitek's office looks for all the world like a color aerial photograph, it is in fact a seamless DEM, or digital elevation model, constructed of millions of data points and analyzable to a resolution of two meters. In other words, Kvitek enthuses, "it shows you everything," and you can ask virtually any question of it. He zooms in to the tidal creeks that loop through pickleweed flats along the slough's north side. "These tidal creeks are really important nursery grounds for fish," he explains, "but the slough is also experiencing really dramatic tidal scour, ever since they opened the mouth to tidal flushing in '46 when they built the harbor. These are 5,000-year-old salt marshes, and they're going away; meanwhile, these tidal creeks are getting wider and deeper, and their value as nursery grounds is changing—they're become more and more like the central channel. So a host of folks is trying to figure out, What do you do with the slough? Do you engineer some sort of a solution, or do you not, do you just let it go? To answer that question, you really want to know how close to equilibrium we are now. If we're 90 percent of the way there, then we can afford to just leave it. If we're 10 percent of the way, maybe we want to do something."

By acquiring airborne lidar bathymetry data sets at fairly frequent intervals (this method is appropriate in the slough because the channel is fairly shallow), we can begin to address these questions. Each time data

are acquired, there will be subtle shifts that we might be unable to discern with our eye—or we may see that there are differences, but be unable to quantify them. The beauty of digital surface models is that the data are entirely numeric: we can quantify—add and subtract and find the difference between last June and now, or five years ago and now—to our heart's content.

On his computer screen, Kvitek shows me a maplike image that—he points with his finger—includes Moss Landing Harbor and extends oceanward: the head of the Monterey Canyon. This DEM combines multibeam and sidescan sonar. "You can see all the landslides down here," he gestures at the screen, "and the dune fields over here; it's clear that erosion is going on, it looks like a really dynamic place." The apparent dynamism made him decide to find out more, and to make it a learning experience into the bargain—one of his hallmarks as an instructor is engaging his students directly in hands-on, cutting-edge research. (In 2004 he won the CSU Wang Family Excellence Award in Natural Sciences, in part for making possible "earn while you learn" student assistantships.)

He toggles two images of the canyon, from September 2002 and March 2003. "Here, you can visually see. But if you subtract those two layers from each other"—he bangs the keyboard, and a new image pops up—"all the cool colors here show where sediment has accumulated, while all the warm colors are where there's been erosion. So now you can see, wow, there's a whole bunch of sediment built up here"—he points again—"and we had erosion along there and down here." Was there an explanation? "It turned out that this happened when they were doing dredging in Moss Landing Harbor [between the two surveys, to keep the harbor channel clear], and that's where most of the dredge spoil ended up."

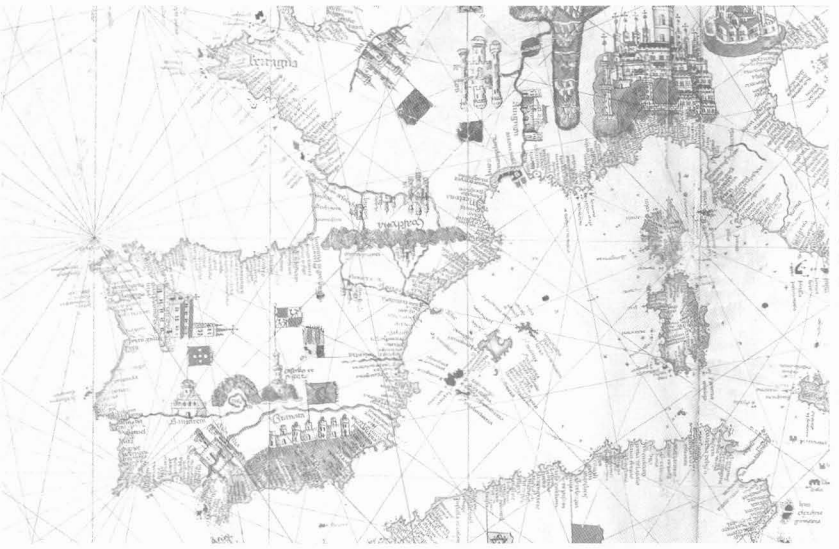
This research, by Kvitek, CSUMB geologist Douglas P. Smith, and others, is causing some basic assumptions to be rethought: because "we're able to look at the process and the dynamics, it's pushing geology more in the direction of traditional science, which is hypothesis testing by actually going out and making measurements." That is in contrast to the traditional approach of geologists, which is "looking at pattern and inferring what must have happened to produce that pattern." The results, says Kvitek, have been surprising. "The prevailing wisdom about the contemporary Monterey Submarine Canyon is that it's either in a somewhat stable or depositional state, with sediments accumulating. Our data suggest the contrary: it looks like it's eroding and that the canyon head is actually moving toward shore, toward the mouth of Moss Landing Harbor." These findings have stirred a lot of controversy, and "vigorous discussion."

Habitat Mapping and MPAs

ONE OF RIKK KVITEK'S many hats is that of science advisory team member for establishment of marine protected areas (MPAs) along the California coast. "Habitat mapping is going to be a key issue if that nearshore resource is going to be effectively managed," he says. "Most people think of habitats as the big blue area on the map, but if you drain the water out you can see that it's extremely complex, just as complex as terrestrial habitats. And that can create a real problem when you're picking MPAs, if all you have to work with is a map like that. If you want to create reserves for deer, you don't want to be protecting parking lots. If you want to create a place for rockfish, then you're going to want to protect rockfish habitat."

He shows me a chart with a thin ribbon of colors extending along the coast, depicting the stretches of water out to the three-mile limit that have been mapped, whether acoustically, with lidar, or in the old-fashioned way. "Right now," he says, "there's (digital) data of one quality or another for some 40 percent of the central coast, but for state waters as a whole coverage is only about 25 percent." In the remaining areas, most often all we have is nautical charts and

Detail of the Canepa portolan chart showing the western Mediterranean



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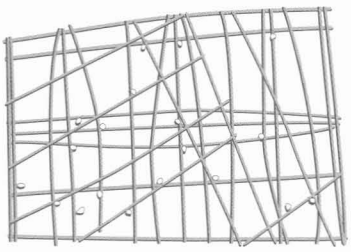
DRAWING BY VALERIE WINEMILLER



A *rebbelib*, or stick navigational chart from the Marshall Islands, c. 19th century. Vertical and horizontal sticks support others that represent wave patterns; cowrie shells represent islands.

geology maps. Kvitek's goal is to get all state waters mapped, over a six-year period, using the most advanced techniques available; the result will be full coverage in high-resolution DEMs—analyzable to half a meter or less. His collaborators in this work include USGS geologists Patrick Barnard and Dan Hanes. "The beauty of it is, you get the highest-resolution data that you can, and then whatever species, whatever questions you're interested in, you go back into those data and get your answers."

The level of detail extends well beyond the information provided by traditional geologic maps—the difference between rock and sand, say. Kvitek calls up a DEM of an area of shale beds off Del Monte Beach in Monterey, then launches a rugosity algorithm; the output is a new map showing rugosity, or bottom roughness. Not only does the computer do the calculations in a snap, but the scale of analysis can shift larger or smaller depending on the species being examined. "This is important for critters like white abalone," he says, "which like that interface right where the boulder comes down, just before it hits the sand." Older-style geologic maps are drawn at too small a scale to get at that difference: everything would be lumped together under rock, virtually erasing white abalone habitat.

These powerful techniques allow Kvitek and his team of student researchers to address issues of fish distribution and stock size in relation to habitat complexity. "It's a lot easier," he says, "to map habitat than it is to count fish." He calls up video footage of those same shale beds, zooming in as the camera moves across the seafloor toward the rocky reefs. "What you have is lots of ledges along here. Some are high, some are low, and in some places there are no ledges. If you take an ROV ride along the flats approaching that ledge, you don't see a lot of fish, but as you get up on the ledge—it's about two meters high—it's just stacked with fish, there's lingcod and greenling and rockfish." Indeed: I see dozens of fish peering out of their holes, wondering, no doubt, what this large bullet-shaped creature is that's zooming past, shining a bright light in their eyes. "You can see all these voids in here where the fish like to rest. It's really ideal habitat. And so if there's a way to find that kind of habitat, and if you know roughly what the densities of fishes are in those sorts of habitats, then you can make some kind of a guess as to what the fish distribution is."

To accomplish all this, the first step is to find out precisely what fishes are in various habitats. This Kvitek did the conventional way, "running a bunch of ROV transects about a mile and a half long. We identified every fish we saw, measured it, counted it, and got its position so we could make a map. And then we created a number of surface models that we tried to correlate with the fish," he says, flipping through maps on his computer screen depicting such variables as depth, slope, and rugosity. They also created a TPI, or topographic position index, which "takes a surface model and breaks it up into different landscape features"—he points at a multicolored legend: peak, ridge, or ledge; upper slope, mid-slope, lower slope; flat; and valley. His analysts then selected a scale that was appropriate for the habitat type and the various fishes that they found there. "And then all of those models were used to produce a distribution or probability map for where individual fish species ought to be. We ran one for shallow species, where the warm colors"—again he points to a prominently red-orange area of the screen—"show where you'd expect to find shallow species, and the cool colors show where you wouldn't; and we also did one for deep species. These models captured over 85 percent of the distribution of the fish."

Eighty-five percent: that is a high level of predictability for a landscape that until very recently—almost yesterday, in the grand scheme of things—was cloaked by a flat wash of light blue.

The capacity to use maps as powerful predictive tools is a real boon in the contentious, real-world business of setting aside habitat for protection of dwindling species. Just as significantly, the fact that maps can serve as accurate, and meaningful, pictures of the undersea landscape will allow MPA advocates to present nonscientists with something they can easily relate to. Both these qualities of the modern "map" will no doubt change the way we use and view our nearshore natural resources. It is no longer possible to say, "But we don't really know what's down there." We know more and more all the time, and we can show what we know in a highly scientific yet intuitively understandable way. In making decisions about MPAs, of course, many factors other than accurate mapping come into play.

"I find it just stunningly beautiful to look at some of these images," says Kvitek, "especially when you lay them out in big sheets showing the habitat. People are taken aback by what's out there. It's been invisible." ■

Derelict Gear

KIRSTEN GILARDI

FOR SEVERAL DECADES, most commercial and recreational fishing equipment has been constructed from synthetic materials that do not decompose in seawater for years. Some of the gear lost over the last half-century is still in the marine environment. Nets, lines, pots, traps, and other equipment lie on the seabed, get caught on rocky reefs, or float in the water column, entangling and trapping marine life, endangering boats and people—especially divers—and damaging habitat.

Fishermen seldom abandon gear in the ocean intentionally: the loss of a large gillnet or a set of crab pots is a significant economic blow to them. However, it is not uncommon for a line attaching a piece of gear to a vessel or a float to fail, or to get cut by another boat's propeller. Sometimes stormy weather will wash a pot, trap, or net far from where it was put in the water, so that the fisherman can't find it when he returns to harvest his catch.

The cumulative impacts on the marine environment can be enormous. Around the Northwestern Hawaiian Islands, hundreds of tons of fishing nets clog the reefs, tear away corals, and entangle marine life, including sharks, birds, sea turtles, and the endangered Hawaiian monk seal.

Between 1982 and 2000, divers found more than 200 Hawaiian monk seals drowned in derelict nets—in 1999 alone they found 25, according to studies by Raymond Boland, Mary Donohue, and others published in *Marine Pollution Bulletin.*

In Puget Sound and the Northwest Straits, hundreds of crab pots and gill nets have been documented on the seafloor and on underwater rocks. Gillnet fishermen there report that they lose 10–20 percent of their gear every year, and in surveys for bottom fish in Puget Sound and Hood Canal, the Washington Department of Fish and Wildlife recovered more than 100,000 pieces of derelict fishing gear in their sampling nets during just one year. Off the San Juan Islands, divers observed piles of bird bones as high as three feet under a gill net caught on some rocks. The bones had drifted down from decomposing carcasses. The problem is global, and California is not exempt. Off the North Coast, numerous crab pots are lost in the water each year. Often, by the time the Department of Fish and Game has a chance to go pull some of them out of the water, many are embedded in the seafloor and impossible to drag to the surface. Along the Central Coast and off the Channel Islands, underwater surveys have found derelict gear draped over rocky reefs, some of it "flagging "—waving in the water column.

No scientific studies have been done on the impacts of derelict fishing gear on marine life in California waters. Every year, however, wildlife rehabilitation facilities along the coast care for seals, sea lions, and birds that are brought in with severe injuries due to entanglement.

Fortunately, derelict fishing gear in the ocean is a problem we can do something about: we can remove it.

The nation's first comprehensive effort to do this began in the Northwestern Hawaiian Islands in 1988. So far, NOAA Fisheries (formerly the National Marine Fisheries Service), working with 16 other agencies and organizations, has removed 495 tons of

KIRSTEN GILARDI

Derelict crab pots removed from water near Anacortes, Washington

derelict gear, according to Mary Donohue of the University of Hawaii Sea Grant College Program in Honolulu.

In 2002, a second program was launched in Washington state. Nearly 1,000 nets, pots, and traps have been removed from the water since then. Nearly 500 entangled fish—including endangered salmon and rockfish species—and four marine mammals have been counted. In this program, the Northwest Straits Commission and the Washington Department of Fish and Wildlife have teamed up with Natural Resources Consultants, Inc., of Seattle. Much of the actual removal is done by sea urchin fishermen—experts at working long hours underwater—who work for the program during their off-season. After the gear is located by sonar, as well as visually by SCUBA divers, the removers, wearing dry suits and breathing surface-supplied air, descend into the water and detach the objects found.

Removing a net draped over rocks without harming marine life requires careful cutting and gentle detachment. Nets and pots embedded in muddy or sandy bottom are freed by hand-digging. If a live animal is enmeshed or trapped in the gear, the diver gently disentangles it and sets it free.

A hydraulic winch is used to lift the gear to the surface and bring it aboard. On deck, the team biologist collects data on the type of gear (e.g., recreational vs. commercial), and the number and species of dead organisms present, if any. Carcasses are returned to the water to decompose naturally or be scavenged.

"It is so personally satisfying to realize that a substantial quantity of derelict fishing gear can be removed in just one day of work," says Tom Cowan, director of the Northwest Straits Commission. "That gear may have been needlessly capturing and killing fish, shellfish, marine birds and mammals for literally decades. While many marine restoration projects take years to plan and implement, removing derelict fishing gear provides immediate and quantifiable results."

The programs in Hawaii and Washington state have served as models for a pilot program launched this past summer in California by the Coastal Conservancy and the SeaDoc Society, a marine ecosystem health program of the University of California, Davis, Wildlife Health Center. The Northwest Straits Commission is making a $25,000 in-kind contribution, using some of the funds allocated by the National Oceanic and Atmospheric Administration for removing derelict gear from waters around the country, and the Laurel Foundation has provided $20,000.

Certified SCUBA divers will be hired to remove gear, using field-tested techniques. Like the programs in Washington and Hawaii, the California program is designed to operate on the "no-fault" principle. It will encourage the reporting of derelict gear by not assigning either blame or penalties. As in Washington, recovered gear will be returned to owners if they can be identified.

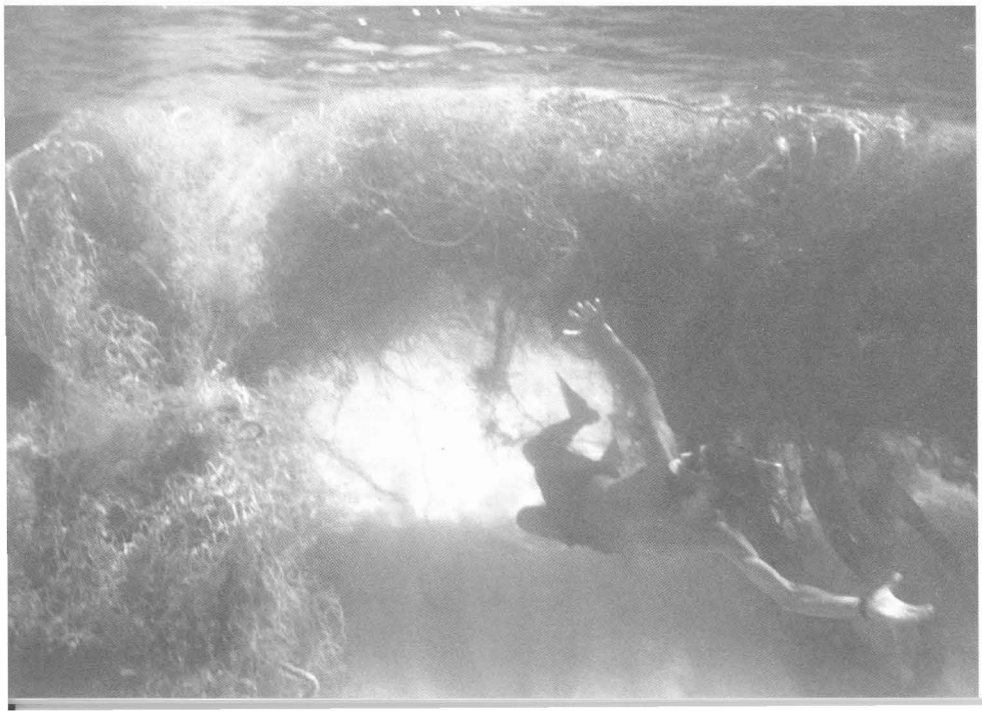
The pilot program will focus on state marine waters in four areas: Catalina Island, Morro Bay, Point Lobos to Elkhorn Slough in Monterey County, and Humboldt Bay to Trinidad Head in Humboldt County. The SeaDoc Society will set up web-based and toll-free reporting systems, so that fishermen, divers, and boat operators can report derelict gear they happen upon. After the pilot project is completed, in about a year, it is expected that the program will be expanded statewide. ■

Kirsten Gilardi, a wildlife veterinarian, coordinates the California Derelict Fishing Gear Removal Pilot Project. She is assistant director of the U.C. Davis Wildlife Health Center and executive director of the SeaDoc Society, which operates in California and Washington state. SeaDoc generates new scientific information for marine stewards at the local, state, and federal levels through research and translation of science to decision makers. See www.seadocsociety.org and also www.vetmed.ucdavis.edu/whc.

Below: A diver with derelict fishing nets hauled out of Puget Sound

Bottom: John Gilardi dives under a mass of derelict fishing nets off Midway Atoll.

JEFF JUNE/NORTHWEST STRAITS COMMISSION



JAMES GILARDI

CONSTANTINOS PETRINOS

DAVID BEHRENS

DAVID BEHRENS

Entranced by Nudibranchs

HAL HUGHES

Top left: An aeolid nudibranch (*Favorinus* sp.) eats the eggs of a dorid nudibranch (*Hexabranchus* sp.).

Top right: *Dirona albolineata*

Above left: *Hermissenda crassicornis* is one of the most beautiful and common Pacific Coast nudibranchs.

(See color images at www.coastandocean.org)

SLUGS: SLIMY, SQUISHY, icky garden pests; startlingly huge banana-like woodland creepers; snails without the pretty shells—what's there to like about slugs? It's hard to imagine that there are thousands of species of slugs that are among the most beautiful, fascinating, and diverse creatures on the planet, but it's true. The secret is that they're marine animals that live mostly out of sight of land-dwelling bipeds. Digital underwater photography and video, in combination with the Internet, are bringing awareness and appreciation of these little jewels of the sea to a broader audience.

The sea slugs belong to a subclass of marine mollusks called opisthobranchs, which are closely related to sea and land snails and to slugs. They are soft-bodied, and most have no shells (though some have small or vestigial shells, sometimes hidden inside their bodies). They live in ocean waters around the world. The best known are the nudibranchs, of which there are more than 6,000 named species, with another 800 to 1,000 still undescribed. Along the California coast, 215 species have been identified, with eight to 15 still unnamed.

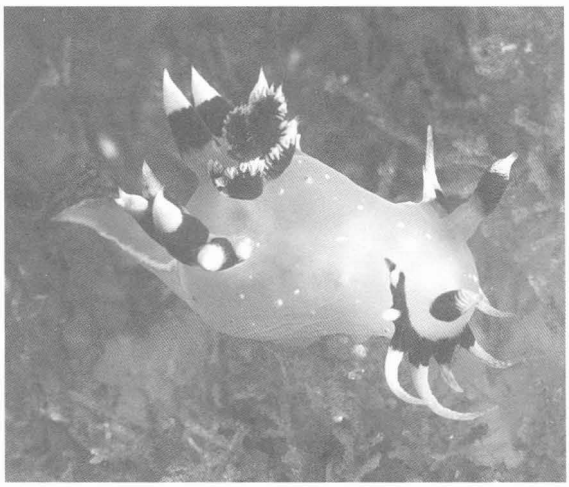
I FIRST SAW A LIVE nudibranch in 1999, when Tim Anderson pointed out a gorgeous *Hermissenda crassicornis* crawling across his "Fouling Species Study Station" in Bahia Cerritos Marina, on the Los Angeles–Orange County border. (See *Coast & Ocean*, Winter 1999–2000.) It was not until I was researching last issue's story on eelgrass, however, that I discovered the on-line resources that are so rich in images and information. I found myself drawn back to these sites again and again, intrigued not just by the extraordinary creatures, but by the community of people who photograph and study them.

As I learned more about the branchs (the "ch" in both nudibranch and opisthobranch is pronounced "k", and the groups are commonly and inclusively referred to as "branchs"), I got an increasingly strong sense of that community. Divers, marine biologists, photographers, and just plain enthusiasts are drawn to these creatures and eagerly share their discoveries with each other. Like birders obsessed with completing their life lists, devoted sea slug fans will travel the globe to dive in search of rare or undiscovered species.

Though new species are not fully recognized until they've been formally described in the scientific literature, many have been found by non-scientists. It often takes only a single encounter with a nudibranch to create a new "brancher." Jeff Goddard, an assistant research biologist at the University of California, Santa Barbara, confided that "no matter what they say, any brancher is into it for aesthetic reasons." Paraphrasing the late Thomas E. Thompson, a British branch expert, he said that "opisthobranchs are to other mollusks what butterflies are to other insects, or orchids to other flowering plants."

H. crassicornis turns out to be an excellent recruiter for budding branchers. One of the most colorful and common nudibranchs in California waters, it's a real attention grabber. Goddard too was drawn in by this lovely animal. "In the seventh grade I had sold my tropical freshwater fish and was collecting creatures from the shores of Richardson Bay in Marin County," he told me. "I found this blue and orange blob stranded out of the water on a muddy rock and, wondering what it was, I collected it. Upon returning home, I dropped the blob into my aquarium, and this exquisitely delicate animal with iridescent blue lines and bright orange tentacles unfolded and started crawling, and I was hooked!"

Polycera tricolor



KEN ASHMAN

THE NUDIBRANCHS (meaning "naked gills") are distinguished from other opisthobranchs ("rear gills") by breathing either through gills that are outside their bodies (the dorids) or through their skins (the aeolids and others). The gills of sea snails are protected by their shells, but as opisthobranchs evolved, their shells became smaller, giving only partial protection, and eventually, in the nudibranchs, disappeared altogether. Dorid nudibranchs bear their gills on their backs as circles of plumes. Aeolid respiration is aided by cerata—elongated tentacle- or finger-like protrusions from their mantles that greatly increase their skin surface area to help absorb oxygen from the water. These unusual breathing mechanisms are among the myriad anatomical variations that make these animals so intriguing.

The cerata are often graceful and beautiful, ranging in shape from slender and pointed to bulbous, flattened, or even intricately branched. They usually also contain extensions of the branch's digestive apparatus. Some "solar-powered slugs" ingest single-celled plants called zooxanthellae, which they store in translucent cerata. These slugs live in shallow waters where sunlight can be photosynthesized by the zooxanthellae, providing supplementary nourishment for the slug. Many branchs, including the kelp-dwelling *Melibe leonina*, are able to shed their cerata when disturbed by predators, leaving the appendages behind as distractions so the slug can escape alive.

The remarkable diversity of the sea slugs is due in part to their extreme specialization: many occur only in specific ecological niches, and most eat only one kind of food, sometimes things that other animals find inedible, such as sponges, bryozoans, and corals. The diet of an opisthobranch is significant in many ways. Many species, such as the sponge-eating dorids, look remarkably like their food sources in both color and texture; this cryptic quality camouflages them, making them hard to find in their natural habitat.

Many branchs, however, have brilliant colors and patterns that would stand out in any habitat. The bright colors and fascinating behavior of nudibranchs were what attracted Christopher Kitting, now a professor of biological sciences at California State University East Bay (formerly Cal State Hayward), as a high school student enrolled in a summer program at Humboldt State University. Vivid coloration is understood to be a way for sea slugs to warn predators that they are unpleasant or even dangerous to eat—an example of the impressive array of defenses these soft-bodied creatures have developed. Some aeolids eat anemones or cnidarians (jellies and their relatives) that contain stinging cells. The slugs somehow

CONSTANTINOS PETRINOS

KEN ASHMAN

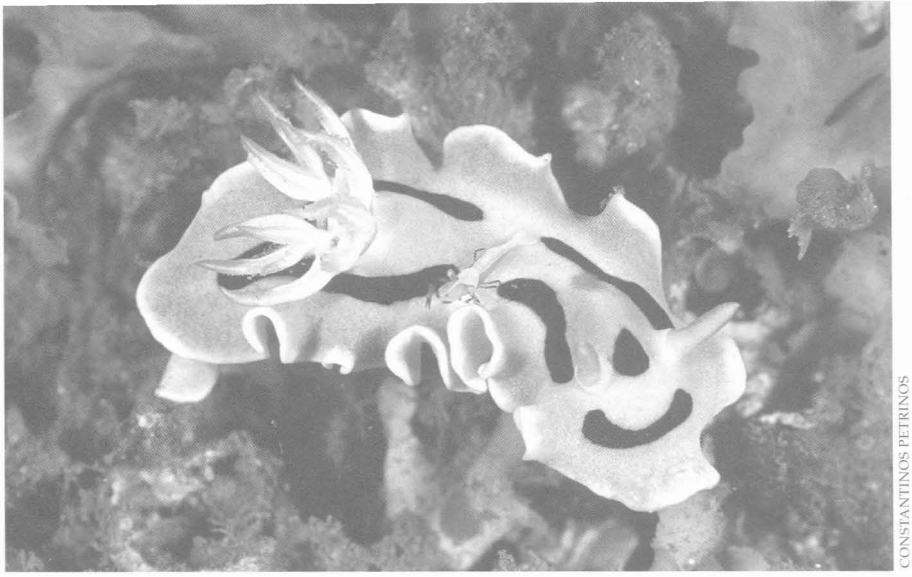
are able to neutralize or coat the stinging cells, then transport them to their cerata, where they are stored until needed for the aeolids' own defense. One of Kitting's students touched an *H. crassicornis* to his tongue, which swelled up rapidly and painfully and took days to return to normal. Kitting also described an experiment by Dean Kellog, a former student, wherein fish were exposed to lures resembling nudibranchs, which they nibbled on freely. One taste of a real branch, however, was enough to make the fish reject not only the slug, but the harmless lures as well.

Some sea slugs can similarly process the chemical defenses of their prey for their own use. Even more remarkably, some can synthesize their own, often unique, chemical defenses, then secrete them from glands in their mantles. At least one species can secrete sulfuric acid for self-defense!

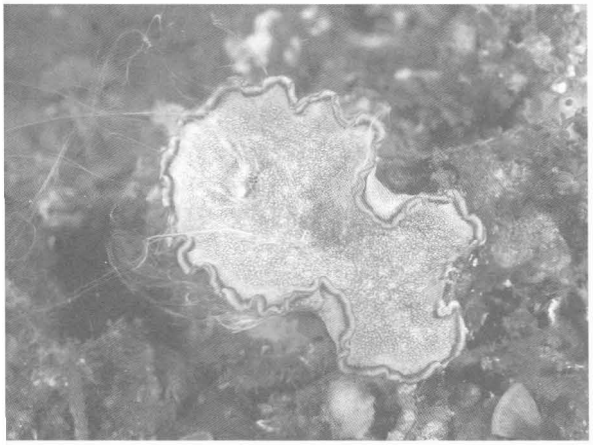
ONE GOOD INDICATION that sea slugs are unfamiliar to most land dwellers is that only a few, such as the Spanish shawl and Spanish dancer, have popular names. The naming of nudibranchs is interesting in itself. New genus names come seldom, but new species are being named all the time, often in relation to the branch's appearance, where it was found, who found it, or in honor of noted scientists. Sometimes, though, branchers enjoy the more personal side of taxonomy, naming species for friends or family members. This can be a delicate proposition, as Dave Behrens, a research associate at the California Academy of Sciences, points out in his comments regarding a species he named: "The decision to name a species after your wife is one that a researcher should not make lightly . . . . Naming a slug after your wife, are you crazy? . . . Is this critter beautiful enough, humble enough, impressive enough, classy enough, enough, enough. In this instance I believe, and now Diana concurs, that *Chromodoris dianae* is all those things." Descriptions of two species with the species name *behrensi* will be published soon, he added.

When Behrens was a student at Merritt Junior College in Oakland he collected nudibranchs at the Berkeley Marina, fascinated especially by their gills and rhinophores (antenna-like sensory organs). Later, at San Francisco State University, as part of a science project, he tied a rope around a mayonnaise jar and suspended it from a dock. Among the creatures that found their way into the jar was a nudibranch, *Ancula pacifica.* His instructor recognized that this species previously had not been found as far north as San Francisco Bay, so he recommended that Behrens write up his discovery and publish it.

A newly discovered species remains in a sort of limbo until someone is able to name or describe it. Terry Gosliner, a long-time brancher who is now provost of the California Academy of Sciences, described the process: "When you first see an animal, there's a gut feeling whether it's been seen before. With some, like the dorids, the differences are often internal, so recognizing new species can be problematic. You have to match what you've found against your knowledge and experience. First you iden-



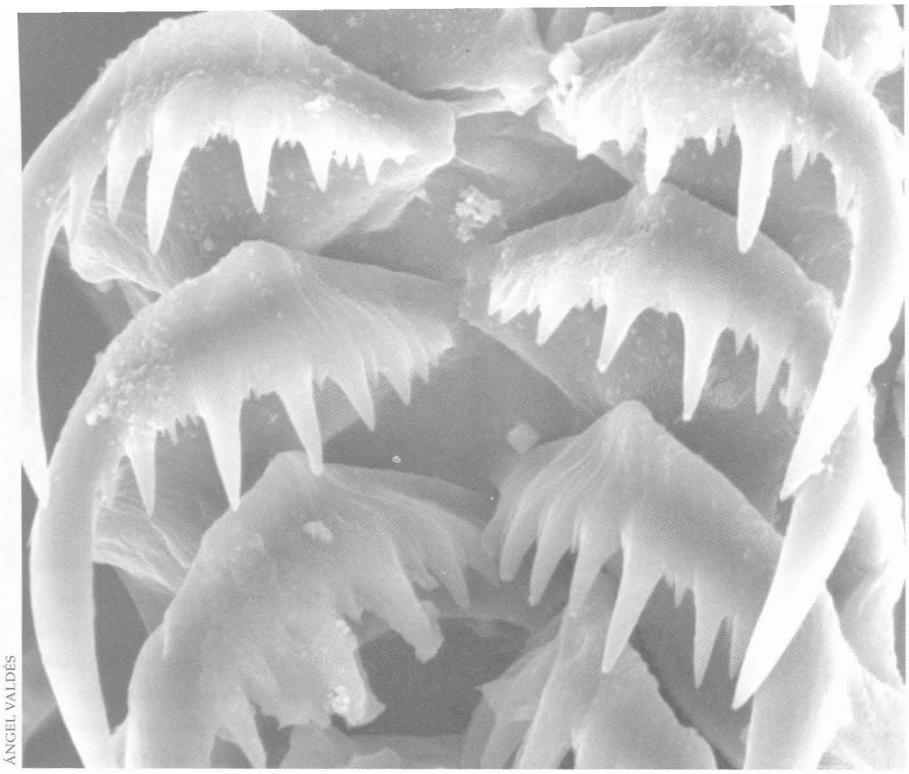
CONSTANTINOS PETRINOS



Top: *Chromodoris dianae*, named for Dave Behrens's wife, shows the distinctive gill plumes of the dorids. This one carries a hitchhiking shrimp *(Periclimenes imperator)*, which picks up food along the dorid's path.

Left: *Glossodoris hikuerensis* secretes acid from its mantle for self-defense.

Bottom left: the Spanish shawl *(Flabellina iodinea)* preys on an orange hydoid, then processes its pigment into three color states: orange, violet, and scarlet.



ÁNGEL VALDÉS

A scanning electron microscope photo of the formidable radula of *Trapania* sp.

tify the genus, then compare the animal to similar species and review the literature to find whether it's been identified. If you find that it's new, you write a paper describing it and illustrating the differences that set it apart from described species in a format that will be convincing to your colleagues. Then you submit the paper to a journal, where it will be reviewed by two branch experts who decide whether it is convincing, and if so, it's finally published."

Most branchers, scientists or not, are divers and photographers, and good color photographs are of enormous benefit in identifying species. After college, Behrens worked for PG&E, supervising marine monitoring at the Diablo Canyon nuclear power plant, where he again found many branchs. He realized that there was no book with color photographs of Pacific Coast branchs, so he decided to write one. Around the same time, a coworker, Daniel Gottshall, founded Sea Challengers to publish his own book on fishes. In 1980, Sea Challengers published Behrens's *Pacific Coast Nudibranchs,* followed by a revised edition in 1990. A further revision, retitled *Eastern Pacific Nudibranchs,* is forthcoming, as is his *Nudibranch Behavior.*

"To find branchs, you need a good eye," said Goddard. In the intertidal, he elaborated, "branchs prefer rocky, shaded habitats: caves, cobble, boulders, nooks and crannies—the places where encrusting invertebrates (sponges, hydroids, bryozoans) and their predators thrive. On early summer mornings when the tide is low, the water is calm, and the sky is overcast, branchs come out and are easy to find. I've seen as many as 30 species in a single low tide. Branchs can crawl off rocks and hang upside down along the surface tension of the water surface, where they're very conspicuous. The brightly colored species stand out against the algae. You can collect the sapsucking saccoglossans by collecting algae and just waiting for the slugs to crawl off."

There are many excellent opisthobranch web sites, with abundant photos, videos, and links. A good place to start is Mike Miller's Slug Site: http://slugsite.tierranet.com.

MOST SEA SLUGS are small, under two inches in length, but some are quite large, and may grow even larger in captivity. A California sea hare *(Aplysia californica)* that was held in a tank and kept from breeding grew to weigh 40 pounds, a world record. Another sea hare, *A. vaccaria,* which also occurs in California waters, has been observed *in situ* up to 30 inches long, and may be the biggest sea slug in the world.

Ángel Valdés, now associate curator of malacology (mollusk studies) at the Natural History Museum of Los Angeles County, grew up by the ocean in the northern Spanish province of Asturias, where he loved collecting seashells. When he was 16 or 17 he saw his first nudibranch and, struck by its beauty, decided he wanted a career studying these creatures. At the nearby University of Oviedo he met a nudibranch specialist who encouraged him, and soon he was publishing papers on his discoveries. Experimenting with aeolids in aquaria, he found that when they are fed abundantly, they grow rapidly, but if food is scarce, they shrink again—an indication that their size at least partly depends on available resources.

Branchs feed in a variety of ways. Most possess a radula, a ribbonlike oral structure lined with rows of teeth, with which they can rasp away at a sponge or other prey and grind up the bits to swallow and digest. (The structure of this organ, revealed by examination with a scanning electron microscope, often is a key to differentiating species that resemble each other outwardly.) When the translucent nudibranch *Melibe leonina* spreads its fringed oral veil to catch its prey, it resembles a fisherman casting his net. The vegetarian saccoglossans puncture fronds of kelp or blades of seagrasses and suck out the sap or soft inner tissues.

Opisthobranch locomotion in the main resembles that of snails and terrestrial slugs: they glide along on a trail of slime. Among marine slugs, however, the range of movement is much broader. Some are very slow, even almost stationary, but others can move

quite rapidly, especially to avoid a predator or to capture prey. I found a video on the Internet (www.life.uiuc.edu/slugcity/movies.html) of a *Navanax* stalking and devouring a *Hermissenda.* The predator crept very slowly toward its prey, but once it was within feeding range, it expanded its mouth tube, engulfed the other slug, and gulped it down whole in a split second.

Many branchs can swim, by flapping wing-like extensions of their mantles, rippling their bodies from front to back, or even using fishlike side-to-side movements of their vertically flattened tails. For some species, swimming seems not so much a way of getting from one place to another as a reflexive response to being disturbed or dislodged. A few slugs, however, swim well enough to spend much of their lives in the water column.

BEING SOFT-BODIED, nudibranchs have left no fossil record, so understanding their evolution depends on analyses of how living species are interrelated physically and geographically. Opisthobranchs that have small or internal shells, however, have left fossils that have been well studied. Valdés says that these show a very clear evolutionary progression from large heavy shells gradually through small fragile shells to a complete lack of shells. Living sea hares, for example, have small, flat internal shells, but their ancestors of 23 million years ago had rounded external shells, much like today's *Bulla* opisthobranchs. Though nudibranchs have had to develop other ways to defend themselves, this evolutionary change freed them from the energy burden of producing shells and enabled them to inhabit niches where shelled creatures cannot go.

Valdés noted that "nudibranchs have been able to colonize all marine environments, from the surface of the open ocean to the deep sea, tide pools of rocky shores to sandy abyssal flats, from the frigid polar oceans to the tropical coral reefs. Every single marine ecosystem, including hydrothermal vents, has nudibranchs." Indeed, one species of *Dendronotus* has been found preying on hydroids around deep hydrothermal vents. Deep-sea branchs include representatives of several genera, indicating that there have been separate migrations to the depths, rather than evolution and spread of species from a single genus that was well suited to such conditions. Most deep-sea slugs are completely white (as are most polar species).

Opisthobranchs are hermaphroditic, with both male and female sex organs, usually located together on the right sides of their bodies. To mate, two individuals line up side by side and head to tail to align their opposite organs. Both will then lay copious egg masses, often shaped like coiled ribbons, sometimes colored to match the slug that lays them. These egg masses may be far more conspicuous than the branchs themselves and provide good clues that sea slugs are nearby.

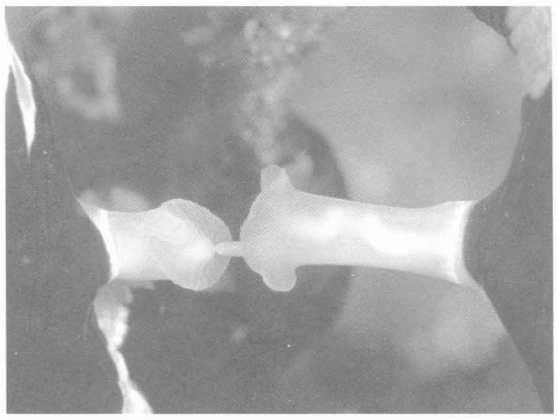
Some slugs use different mating strategies. *Aplysia* may form chains of up to 30 individuals, in which the animal at the head of the chain engages only its female sex organ, and that at the tail only its male organ, the rest engaging both. Others mate by penetrating the body wall of their partner with a spine that injects sperm directly into the body cavity, where it must find its way to the unfertilized eggs. Others have genital hooks (both penile and vaginal) that keep mating partners securely engaged. In some cases sperm may be stored and used for nutrition rather than for fertilization.

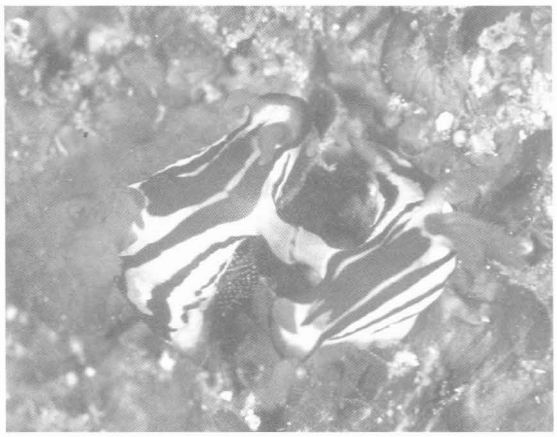
Goddard studies how opisthobranchs develop from egg to larva to adult, and how that progression relates to their habitat. Over 90 percent of eastern Pacific Coast species hatch into veliger larvae (named for the velum, an organ used both for swimming and for gathering food particles) that live as plankton that feed in the water column for a time before settling to the bottom to turn into adults. The advantage of this mode, Goddard said, is that the eastern shores of oceans tend to have slower currents, and upwelling there provides abundant food supplies, making it easier for larvae

Top: Nudibranch copulatory organs engaged—some have minute spines or hooks to maintain a secure connection.

Below: This pair of *Nembrotha megalocera* show how nudibranchs mate head to tail.

Bottom: A *Hypselodoris maritima* lays a ribbon of eggs.





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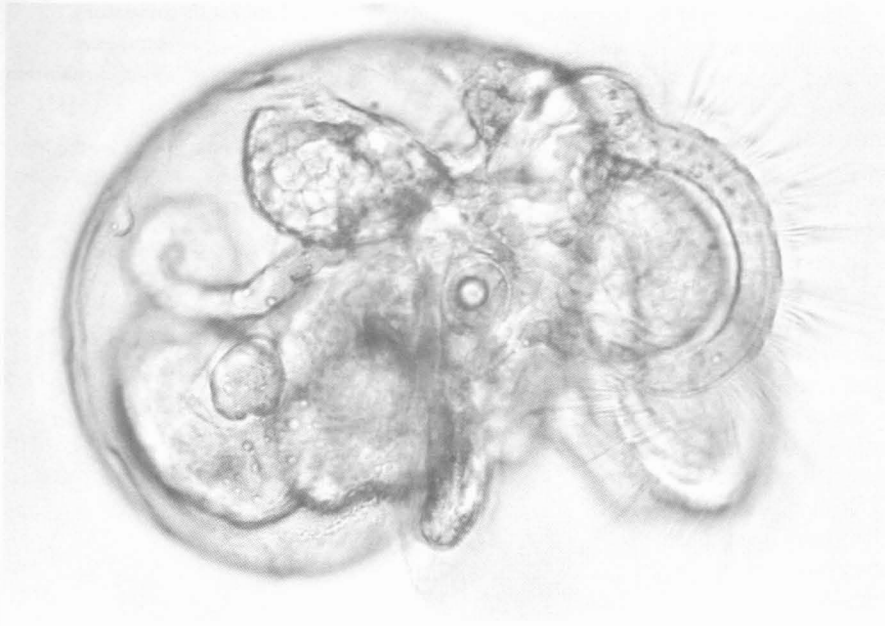


JEFF GODDARD

Top: A veliger larva of *Chromodoris macfarlandi* hatching. Its egg measures less than one-fifth of a millimeter. The velum is the fringed organ on the right. It will live as plankton for weeks or months before settling to the bottom and metamorphosing into an adult slug.

Bottom left: *Philine auriculatus* is invasive in California waters.

Bottom right: *Oxynoe panamensis* could be used to control the "killer alga," *Caulerpa taxifolia*.

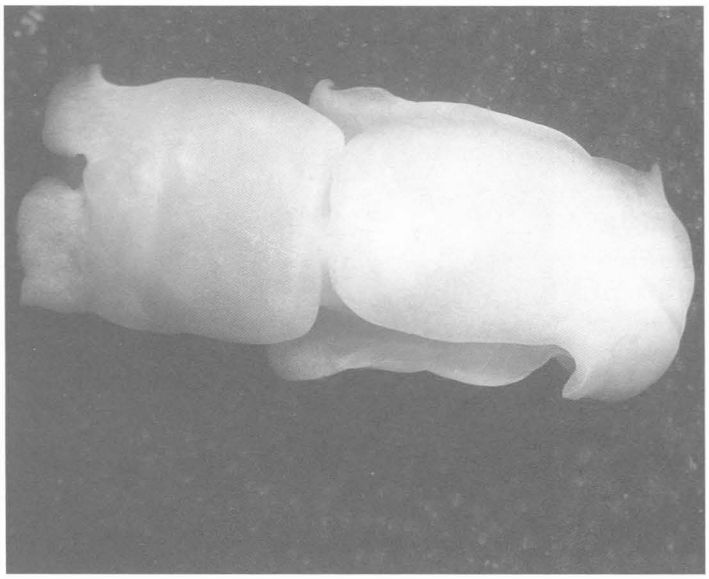
to survive. Some species have larvae that feed on nutrients in their eggs, rather than living as plankton; others hatch as juvenile slugs, rather than as larvae.

Sea slugs may eventually be very useful to humans. They are already of great interest to medical science. Their ability to function as living biochemical labs is being studied not just for better understanding of the creatures, but as possible sources of new drugs. Dr. Fred Fuhrman of the Stanford Medical School has isolated a chemical found in *Anisodoris nobilis* that slows mammalian heartbeats, which could prove useful for human medical conditions. Branchs also have exceptionally large nerve ganglia and simple central nervous systems that are convenient for studies of neural responses. *Aplysia* and *Hermissenda* are both used extensively in research about memory, learning, and behavior, and may be useful in finding treatments for Alzheimer's disease and other human ailments.

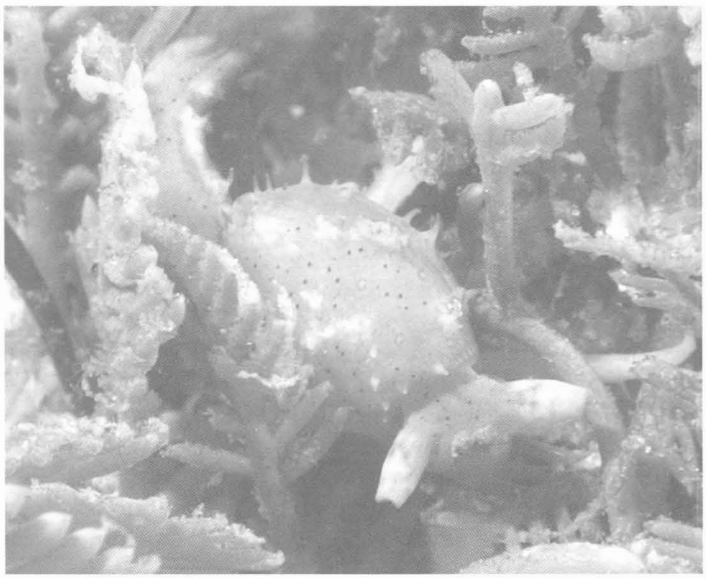
Sea slugs are also of concern both as invasive species and as potential means of combatting them. Fat white slugs of the genus *Philine*, native to New Zealand and the western Pacific, are now found in abundance in California bays. They feed voraciously on native clams and worms and reproduce prolifically—as many as 18 per square meter have been observed in Bodega Bay. Some fear that they may disrupt the food webs of their adopted habitats.

On the other hand, a sapsucking Caribbean saccoglossan, *Oxynoe panamensis*, has been proposed as a possible means of controlling the spread of the "killer alga" *Caulerpa taxifolia*. The wisdom of such a move remains debatable, however. Even though *O. panamensis* eats only *Caulerpa*, there is some trepidation about moving another non-native species into an already troubled habitat.

BEAUTIFUL PHOTOGRAPHS, then astonishing videos, first attracted me to the sea slugs. The more I saw, the more I wanted to understand how these strange-looking creatures functioned. As questions arose, the answers always seemed close at hand, and I was impressed by how eagerly branchers share their data, both with each other and with novices. Their boundless enthusiasm and generosity are contagious. Like the branchers themselves, I became eager to share the wonders of these creatures with others. ■



TERRY GOSLINER



KEN ASHMAN

Santa Barbara Sea Center

ROBERT SOLLEN

PHOTOGRAPHS BY ROBERT BERNSTEIN

Top right: Ty Warner Sea Center

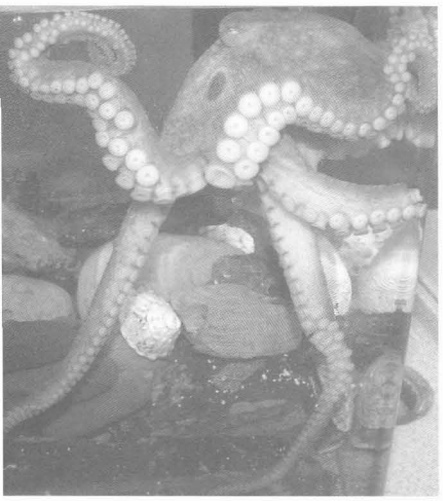
Top left: Two boys look at creatures from inside the tidepool tunnel.

As you enter the lobby of the new Santa Barbara Museum of Natural History Ty Warner Sea Center, passing under a life-size model of a California gray whale and her calf, you are drawn into an ocean realm. To judge by the enthusiasm of the crowds that have flocked through since it opened last April, this new $10-million institution is already fulfilling its stated goal: "To inspire a passion for the natural world and foster stewardship for the marine environment."

Jenny Theodorou, the Sea Center's director, explains that "the idea here is to talk about preservation and conservation, but not beat our guests over the head with it. We don't tell people what to do, but if they understand what's happening, they'll learn to do the right thing."

The two-story, 6,734-square-foot structure that houses the Sea Center stands about a third of the way out on Stearns Wharf, Santa Barbara's popular recreational pier. The center is a museum, an aquarium, and a place where ocean research is dramatized and where exhibits will reflect new scientific material. It's a place to experience close-up and hands-on contact with plants and animals of the Santa Barbara Channel. Instruction is available in a scientific wet lab and documentary films run all day in the small theater.

While dealing with the entire West Coast, the Sea Center focuses specifically on the Santa Barbara Channel, where marine and avian wildlife abounds. More than 60 species of marine birds and 100 species of fish spend at least part of the year there. Among more than 30 kinds of marine mammals that live in or pass through the Channel are porpoises, dolphins, seals, sea lions, and whales, including the blue whale, the Earth's largest living creature. Thousands of people gather on beaches and bluffs to watch the annual gray whale migration between the Bering Sea and Baja California. Tour boats get even closer. At the Sea Center, people can learn more about creatures they might see from the shore or in nearby waters.



A live octopus makes a dramatic display.

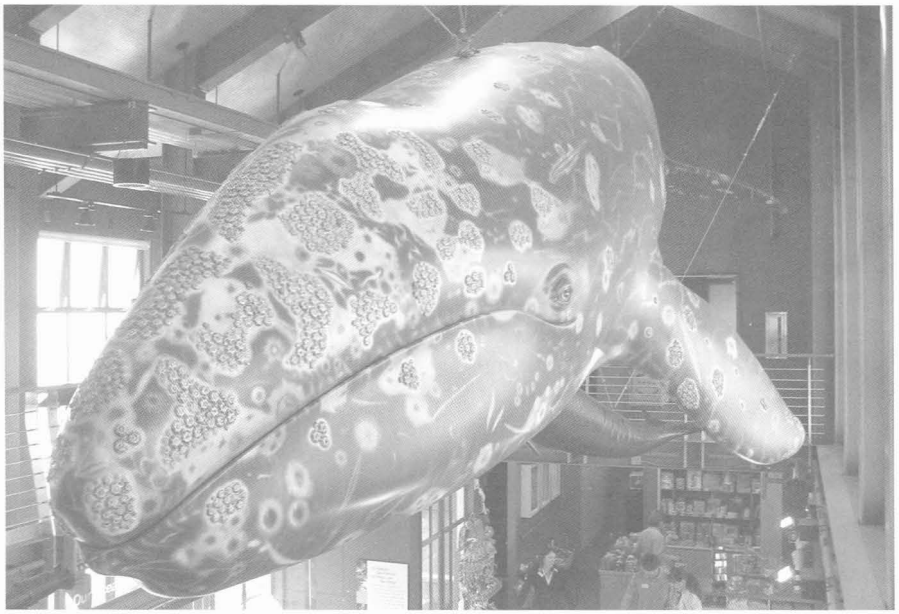
One of the many habitats that support the vast diversity of marine life in the Channel, the rocky intertidal, is demonstrated in a 1,500-gallon exhibit that simulates the ebb and flow of tides and waves over the rocks of a tide pool. You can look over the fiberglass rockwork wall and watch fish, crabs, urchins, snails, sea hares, sea stars, and anemones being inundated, exposed, and inundated again in a continuous cycle. Magnifying lenses are available for a closer look inside the pool, and a video touch screen offers more information. A tunnel with windows runs through the pool. Children enjoy walking through it, looking at tide pool life from an underwater perspective. Adults would have to stoop or crawl rather than walk.

A corps of more than 100 "sea crew" volunteers encourages visitors to touch and examine various marine animals closely. They describe their structure, habits, and habitats. Sea stars, urchins, and limpets rank among visitor favorites. Not every creature may be touched, of course.

A hands-on experience is more than touching, however. A visitor to the Sea Center is likely to see young people at work tables, experimenting with sampling and testing equipment for oceanography, biology, chemistry, geology, and environmental and conservation research.

Among the unusual exhibits is a plastinated seven-foot long-beaked common dolphin that was stranded on a nearby beach and died. She was pregnant, so both she and her fetus were preserved by a process that turns tissue into plastic. Part of one side of her body was left open so that the preserved internal organs can be seen.

A life-size model of a gray whale



Microscopic ocean life can be examined on the "wet deck," 20 feet above the water, where visitors are invited to use five types of oceanographic sampling equipment, including the Eckman Grab. This mechanical set of jaws is lowered to the ocean floor through an opening in the deck. It scoops up samples of sediment, which visitors then examine under a video magnifier.

More than a dozen public and private institutions and agencies cooperate with the Sea Center in research, exhibits, and education. These include the Coastal Conservancy, the Nature Conservancy, the Channel Islands National Marine Sanctuary, Santa Barbara ChannelKeeper, Santa Barbara City College, the Community Environmental Council, the City of Santa Barbara, the National Park Service, the National Oceanic and Atmospheric Administration, the University of California, Santa Barbara, Partnership for Interdisciplinary Studies of Coastal Oceans, and the UCSB Marine Science Institute.

The single largest contributor was Ty Warner, creator of the Beanie Baby toys, who lives in nearby Montecito. His gift of $1.5 million last year enabled the Museum to complete the structure and exhibits. The Sea Center was renamed in his honor. Warner then produced a limited-edition floppy octopus named Opie for the center's benefit. It sold out within weeks.

After five years of planning and construction, the center is drawing a highly positive response from the public. "More than 50,000 people visited during the first four months, many of them more than once," Theodorou said. "In our survey, the public rated us 'good to excellent.' We hope for over 100,000 visitors next year."

Such crowds would have overwhelmed the Sea Center's modest predecessor on Stearns Wharf, which had survived wind, waves, earthquake, and fire, but finally had to be replaced. The wharf area had to be rebuilt to support the current structure, which is two-and-a-half times the area of the old one.

It's there now, firm and dedicated to the delights of discovery and to everything we can learn and do to ease the heavy human toll on ocean resources. ■

Robert Sollen reported on environmental issues for the Santa Barbara News Press *from 1969 to 1985, when he retired. He has since taught environmental journalism at the University of California, Santa Barbara, and has continued writing on political and ecological issues.*

Updates

SIX YEARS AGO

The Eagle in the Fox's House

"It's a classic situation of the fox in the henhouse, only in this case the fox is a golden eagle, the henhouse is an island, and the hen is . . . well, a fox."

"Endangered Species Chess"

Autumn 1999: Vol. 15, No. 3

SIX YEARS AGO, the Channel Islands fox, a dwarf species about the size of a housecat, was in big trouble. Its numbers were falling rapidly on the three northernmost islands—Santa Cruz, Santa Rosa, and San Miguel—due to predation by golden eagles that had migrated from the mainland. The species' survival was in question, and National Park Service biologists leapt into action. Most of the remaining foxes were removed to holding pens and a captive breeding program was instituted.

Today, the foxes seem on their way to recovery. Small numbers of them are roaming free again and appear to be thriving, according to Tim Coonan, head of the island fox recovery team. This is a "banner year," he said, with 81 pups born in the wild.

In addition to capturing the foxes, the recovery team worked to obtain endangered species status for the most threatened of the fox's six subspecies. This was accomplished in 2004, opening up new resources for the recovery effort. The team also began relocating the golden eagles: to date, 41 have been relocated, and Coonan thinks that only three or so remain. Bald eagles, which are native to the islands but were virtually eliminated, largely due to human activities, are being reintroduced to help keep the golden eagles in check; bald eagles, which eat fish and birds rather than foxes, are very territorial. About 30 young birds have been reintroduced on the three islands and seem to be doing well.

Concurrently, hunters are removing feral pigs, which attract golden eagles, from Santa Cruz Island. About half of the estimated 5,000 pigs have been taken, and Coonan expects the islands to be largely pig-free by next summer.

There are about 345 foxes on the three islands now, about 190 of them in the wild, and more of the captive population is being released this autumn. If all goes well, most of the foxes' troubles could be over in a few years.

—*AC, EE*

THREE MONTHS AGO

Spartina Battle Continues

*"Full-scale efforts to eradicate the aggressive non-native Atlantic cordgrass (*Spartina *spp.) from San Francisco Bay are now under way—and not a moment too soon. The problem is reaching the crisis level, according to Maxene Spellman, manager of the Coastal Conservancy–led Invasive Spartina Control Program."*

"At War with Invasive Spartina"

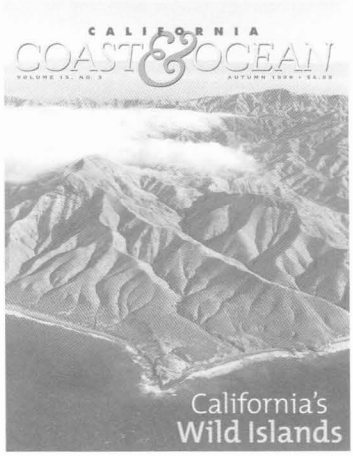
Spring & Summer 2005: Vol. 21, Nos. 1 and 2

IT WAS A SMALL window in time—only a few weeks in September and October when an herbicide could be applied without harming the endangered California clapper rail—but the Invasive Spartina Project (ISP) was optimistic: it had a new weapon for the battle against *Spartina* spp., the Atlantic cordgrass that has been spreading rapidly in mudflats and restored tidal marshes of San Francisco Bay. The herbicide imazapyr had been registered for aquatic uses on August 20 and could now be substituted for glyphosate, which had proved inadequate in 2004 pilot programs.

The ISP had earlier experimented with eradication methods that do not require herbicides, including mowing and smothering the grasses with tarps, but nothing worked. "Mowing does nothing but irritate the plants and make them angry," Erik Grijalva, ISP field operations manager, reported to the Seventh Biennial State of the San Francisco Estuary Conference on October 4.

By November 1, one thousand of the 1,200 infested acres had been treated. The herbicide was sprayed from trucks, helicopters, amphibious vehicles, hovercraft, shallow outboard-motor boats, and with backpack sprayers. All necessary permits are now in place to continue the full-scale effort next year, with hopes that the spread of the invading grasses will be reversed and eventually halted. Experts have told the ISP that "you have a chance now to control [the invader grasses], but not later."

—*RG*



A LOFTY TRAIL NETWORK

BAY AREA RIDGE TRAIL NEARS HALFWAY MARK

EILEEN ECKLUND

Along the Bay Area Ridge Trail in Almaden Quicksilver County Park, southwest of San Jose

THE EARLY-MORNING FOG drip in San Francisco's Sunset district on this June day is so heavy that it might as well be rain, especially under the towering eucalyptus trees in Stern Grove. I can't see far through the thick gray blanket, but I can hear the steady roar of traffic on nearby 19th Avenue and taste the salt tang of the ocean as a stiff breeze blows billows of fog toward the hills. My dog and I head for home as the city wakes up around us. Parents are bundling children into cars; men and women are on their way to work, steaming cups of coffee in hand; joggers, a tai chi group, and other dog walkers are performing their morning rituals.

Later that morning, I'm hiking with a few other reporters on a ranch in eastern Napa County. The golden-brown hillsides bake in the sun, although here and there we see a few late-season wildflowers peeping through the grass. Groves of old oaks provide welcome shade, and below us a creek meanders through a valley. We scramble up a steep slope to a ridgetop, where a spectacular view unfolds at our feet. Below us a crew—the only other humans within miles—is at work on a new trail.

The contrast could hardly be greater, yet these two very different walks in very different places had one thing in common: Both occurred on the Bay Area Ridge Trail, a regional pathway that is forming an extended ring around the Bay, linking parks, open spaces, and communities by means of a network of trails for hikers, bicyclists, and horseback riders. This grand work in progress now covers 274 miles and

by the end of 2005 will pass the halfway mark: current projections put the completed route at 580 miles.

The Ridge Trail follows some of the region's most scenic ridges, including San Pablo and Dinosaur Ridges in the East Bay, Skyline and Sweeney Ridges on the Peninsula, and Bolinas Ridge in Marin County. Along the way it also skirts or climbs some of the loftiest peaks and mountains, including Mission, Redwood, Vollmer, Coyote, and Twin Peaks; Mt. Tamalpais; Sonoma, Burdell, and Bald Mountains; and Borel and Windy Hills. It is one of two concentric trails now under construction around the Bay; the 400-mile Bay Trail runs near the shoreline and is also about half completed. The two trails share some routes where they have to cross bridges, and the hope is to someday link them at various points.

Of the two trails I walked that day, the Fort Funston to Stern Grove route, in San Francisco, was one of the first sections of Ridge Trail to be completed (in 1989), while the Napa-Solano Ridge Trail loop is among the most recent, dedicated in September 2005. The first 100 miles of the Ridge Trail took only a year to finish. They were the easier part of the effort, as they are on public lands and incorporate existing trails through parks and protected natural areas, as well as routes along city sidewalks. For the Bay Area Ridge Trail Council, the organization formed to create the trail network, the work was mainly a matter of coordinating with the appropriate agencies and putting up signs. It took another five years to reach 200 miles, and will have taken 10 more to reach the 300-mile mark, which is expected to happen in spring 2006. It will take years, if not decades, to complete the Ridge Trail.

Although 26 of the remaining miles are along urban roadways and 115 will be on public land, more than half of the planned route will cross private land, and many trail segments will have to be built from scratch. The trail council now focuses more and more on helping public agencies acquire land and trail-corridor easements, negotiating with willing landowners, overseeing trail construction, and arranging for long-term maintenance. In 1999, the council established its Trail Trust program to acquire easements and manage trail corridors. The council also works with local agencies to make sure that the Ridge Trail is part of city and county general plans and other regional plans; it is, for example, in San Mateo County's trail plan and Petaluma's bicycle plan.

The 1.3-mile Napa-Solano Ridge Trail is the first segment to be built partially on private property, on a trail easement donated by the Tuteur family to the Trail Trust. It is also the first segment built by the council itself, rather than one of its partner agencies. "We hope to use this trail as an example to take to other private landowners," said the council's executive director, Holly Van Houten.

A Sometimes Rocky Road

A TRAIL CIRCLING San Francisco Bay along the ridges was first proposed in the late 1960s by William Penn Mott, Jr., the visionary general manager of the East Bay Regional Parks District, who went on to head California's Parks and Recreation Department and then the National Park Service. In 1987, Mott's idea sprang to life when trail advocates established the Bay Area Ridge Trail Council as a project of the Greenbelt Alliance, with assistance from the Golden Gate National Recreation Area and the National Park Service. That same year, plans for the San Francisco Bay Trail were set into motion by former State Senator Bill Lockyer (now State attorney general).

The council established committees in each of the nine Bay Area counties to coordinate community and volunteer involvement.

LAWRENCE RODDIN

The Ridge Trail at Big Rock Ridge, Marin County

ELIZABETH BYERS

EILEEN ECKLUND

A hiker's dog cools her paws along the Big Rock Ridge Trail.

Committee members—volunteers themselves—did much of the early planning, identified potential routes, led hikes to generate support for the Ridge Trail, raised money, and recruited more volunteers. By 1989 the council had hired its first staff member (the staff now numbers six), secured its first funding from the National Park Service and the David & Lucile Packard Foundation, and begun dedicating trail segments. In 1992, it incorporated as a private nonprofit 501(c)3 organization.

Over the years, the council learned how to patch together private and public funding and to work with federal, state, and local agencies, as well as other nonprofit and community groups. Key financial and logistical support, including more than $7.5 million in State park bond funds, has come from the Coastal Conservancy since 1998. The Conservancy is currently funding work on 70 separate planning projects, all in different phases. Other funding came from the Park Service, Bay Area foundations, corporate and individual donors, and membership dues.

Council staff and public agency partners now plan trail routes and reach out to landowners, although volunteers still play an important role, especially by leading hikes and helping to maintain trails. Since 1996, the council's Ridge, Kids, and Stewards program has sponsored outings for schoolchildren. Its quarterly newsletter, *Ridgelines*, has kept supporters informed on progress. *The Bay Area Ridge Trail: Ridgetop Adventures Above San Francisco Bay* (Wilderness Press), a guidebook by Jean Rusmore, is now in its second edition.

Among recent notable victories is an agreement with the San Francisco Water Department that permits some access to the watershed of Crystal Springs reservoir, which had been closed to the public since the 1930s. The water department and some environmental groups had opposed public access because of a concern about potential impacts on water quality and the high concentration of rare and endangered species in the area. In 2002, however, the department agreed to allow some guided tours each week along a 10-mile stretch of service road that runs through the watershed along Fifield and Cahill Ridges.

The Ridge Trail Council is committed to making the entire route multi-use, that is, accessible to hikers, mountain bicyclists, and horseback riders. Where the terrain makes it possible, wheelchair riders are also to be accommodated. About 80 percent of the completed trail is multi-use, and the council hopes eventually either to upgrade sections that are not or provide alternative routes. Nevertheless, some user groups, especially bicyclists, oppose routing the trail through areas where they are not allowed.

The biggest obstacle to completing the trail is likely to be lack of money and manpower for maintaining and patrolling it. "The State doesn't have an operations funding stream, and neither do most local agencies," Van Houten said. Parks budgets have been squeezed for years. A lot of public land remains inaccessible to the public because there's no money to open it up.

According to Van Houten, some of these trail segments on public land are being planned or built, but many are on hold until the council can find either a public partner to manage the land or the funds for operations and maintenance. Finding an entity willing and able to maintain trail corridors on private lands—about 165 miles—may be even more difficult.

The most urgent task right now is to secure the route, according to Abe Doherty, the Coastal Conservancy's project manager for the Ridge Trail. With that in mind, the council is working to persuade private landowners to allow trail easements on their properties. That's where the Tuteur family is a helpful example.

Breaking New Ground

JOHN TUTEUR is Napa County's assessor, clerk, recorder, and registrar of voters. His parents bought the 1,300-acre ranch near the city of Napa as a second home in 1951, and he and his wife have been living on the land since 1966, raising their family, riding horses, and running a small herd of cattle. The Tuteurs have been generous in granting access to their ranch for hikes led by the Ridge Trail Council, the Sierra Club, and other groups. Now the family has donated to the council a trail easement on acreage they purchased in 1973, primarily to prevent a road from being built through that area. Tuteur also hoped that, if they could keep cars out, a trail could someday run through there that would link Napa and Solano Counties. The council's plan does include such a trail, although the Ridge Trail segment on the ranch now is a loop to and from Skyline Wilderness Park. It could eventually go in a number of directions, depending on which other area landowners are willing to participate.

As Tuteur sees it, landowners have four major concerns about public access: liability, trespass, maintenance, and patrol. The first is addressed by California's recreational use statute, which limits private property owners' liability when they allow the public onto their land for recreational purposes, and by the owner's agreement with the entity that holds the trail corridor easement. Routing and landscaping the trail in ways that encourage users to stay on it can help to prevent trespassing. From his own experience with a neighboring park, Tuteur believes that landowners' worries about trespassers are out of proportion. "We've actually had fewer problems [with trespassers] since Skyline Park became our neighbor than we did before," when the property wasn't open to the public, he said. Maintenance and patrol are more difficult issues. Because Napa County doesn't even have a parks department that could take on these duties, Ridge Trail volunteers will assume them for now. Eventually the council hopes to transfer responsibility to a public agency.

On the June afternoon when Tuteur showed a group of reporters around his ranch, it was clear that he loves this land and its history, and is proud to be able to share it. He pointed out the remains of an old stone wall marking the spot where a house stood more than 100 years ago. "There was a homesteader out here till he died in the early 1900s. He's buried here somewhere," he said. We walked through heritage oak woodlands and chaparral, and watched a bridge being built over the creek.

"The most rewarding part [of working on the Ridge Trail] is leaving a legacy to future generations," the Coastal Conservancy's Abe Doherty told me. Having walked with Tuteur across his beautiful land, I can understand that.

At almost 300 miles, the Ridge Trail is already an impressive accomplishment and an important regional resource. It allows city dwellers to escape into nature close to home, and provides opportunities for both children and adults to get outside, exercise, and learn about the land. It links a wide variety of Bay Area habitats, from city streets to rolling grasslands to redwood forests, and it brings communities together to help maintain their natural areas. From its loftiest ridgetop routes, the Ridge Trail reveals at our feet the immense natural beauty of the region in which we live, and shows us how interconnected we are. When it's complete, it will also stand as a testament to the vision, will, and resourcefulness of the citizens who helped make it happen. ■

Eileen Ecklund writes for Coast & Ocean *and is also completing work on* A Wheelchair Rider's Guide to San Francisco Bay and the Nearby Coast, *to be published by the Coastal Conservancy later this year.*

FOR INFORMATION or to volunteer, contact the Bay Area Ridge Trail Council: (415) 561-2595; e-mail: info@ridgetrail.org; or www.ridgetrail.org. For more about access easements and landowner liability, the Coastal Conservancy and Coastal Commission have two booklets, "Happy Trails to You: How to Accept and Manage Offers to Dedicate Access Easements" and "Limitations on Liability for Nonprofit Land Managers." For copies, contact the Conservancy at (510) 286-1015.

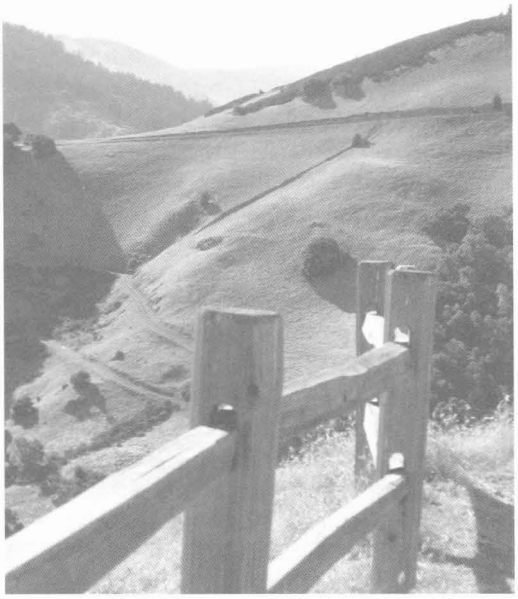
A fiberglass trail bridge crosses Marie Creek on the Napa-Solano Ridge Trail.

BAY AREA RIDGE TRAIL COUNCIL

LAWRENCE ROBBIN

ALMADEN QUICKSILVER COUNTY PARK encompasses more than 4,000 acres south of San Jose. It was the site of some of the biggest mercury mines in the United States from the 1840s to the 1940s. The four-mile section of Ridge Trail that crosses the park was dedicated in April 2004. It winds through grasslands, chaparral, and mixed forests dominated by oaks and bay trees, provides dramatic views of nearby peaks, and connects to 10.5 miles of trail in the Sierra Azul Preserve to the west. In early spring, wildflowers are spectacular. Approach the trail from the park's Mockingbird Hill Lane entrance.

BIG ROCK RIDGE is the high point of Big Rock Trail, a 3.6-mile section of Ridge Trail opened in November 2003. At 1,825 feet, the ridge is the second-highest point in Marin County. The trail climbs through grassland, woodland, and chaparral in the Lucas Valley Open Space Preserve and on easements through private land to the ridge. There you can connect to a fire road that runs east to a radio tower, where views of San Pablo Bay, the East Bay, San Francisco, and Mt. Tamalpais unfold. For a different hike from the trailhead, you can cross Lucas Valley Road and connect to the Ridge Trail's Loma Alta stretch, which runs south for 2.5 miles. The trailhead is off Lucas Valley Road about four miles west of San Rafael.



EILEEN ECKLUND

DAN ROBBIN

BENICIA STATE RECREATION AREA overlooks Carquinez Strait from the Dillon Point peninsula. The two-mile section of Ridge Trail there was dedicated in 2003. It shares a route with the Bay Trail and was built for wheelchair riders as well as pedestrians, bicyclists, and horseback riders. The trail skirts a native plant garden, then climbs gradually across grassy hills with sweeping views of the strait and the East Bay hills beyond. This trail section connects to other trails that lead both east and west. The entrance to the recreation area is off I-780 in Benicia.

COYOTE LAKE–HARVEY BEAR RANCH COUNTY PARK, in the Santa Clara County hills east of Gilroy, has been expanded to include thousands of acres of previously inaccessible ranchland. Now comprising 4,595 acres, the park has 13.6 miles of trails. The Ridge Trail route, opened in May 2005, runs 4.5 miles through steep grasslands and oak woodlands along a western ridge, with views of Santa Clara Valley to the west and Coyote Lake to the east. Approach from the Mendoza Ranch entrance, off Roop Road east of Gilroy.

BAY AREA RIDGE TRAIL COUNCIL

REINVENTING A LOCAL FISHERY ON THE MORRO BAY WATERFRONT

Morro Bay

MARC KURTH

RASA GUSTAITIS

Morro Bay from North Point Park, two miles north of Morro Rock; Duke Energy power plant at top left

THEY WERE STANDING on the Embarcadero, outside one of the tourist-oriented shops, as if trying to decide where to go next. They looked so content and friendly, and so obviously weren't locals, that I was emboldened to ask: "What brought you to Morro Bay?"

"The charm of a small seaside village," answered Bob Miller, of San Clemente. He and his wife had been driving down the coast and decided to stop in the town. "We came here several times with the children in the '70s, when we lived in Anaheim," Celine Miller explained. "We tried to find the place where we had clam chowder—and we did find it." They had concluded that the town hadn't changed all that much.

It was early afternoon on a lovely September Wednesday, and the Morro Bay waterfront was pretty quiet. On the Embarcadero, banners at shop doorways stirred in the light breeze. From the boardwalk along the glittering water, a few small boats were visible near Morro Rock, the ancient volcanic plug that is the main local landmark. The Rock is home to two pairs of nesting peregrine falcons, as well as plovers, guillemots, cormorants, and other birds. In the past, stone was quarried from the Rock, using explosives, to build roads and harbors. Now it's a wildlife reserve.

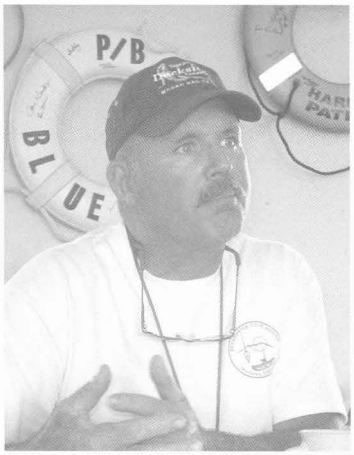
At the south end of town, a small boy and his mother had Tidelands Park to themselves, with its playful sculptures of sea mammals and a wooden-boat climbing structure. To the north, on the wharf near the three smokestacks of the Duke Energy power plant, a couple of fishermen were putting away their gear.

The Millers had whetted my appetite for clam chowder, so I headed north along the waterfront and soon arrived at the Li'l Hut, where I found chowder on the menu posted beside the take-out window. "The clams are local, right?" I asked. "Nope," was the response from within. "Well, I'd like something local, so what's local?" "There's nothing local. Everything's from somewhere else," answered the manager, Tammy Jones.

Top: Mark Tognazzini

Middle: Tammy Jones

Bottom: A foggy day on Morro Bay



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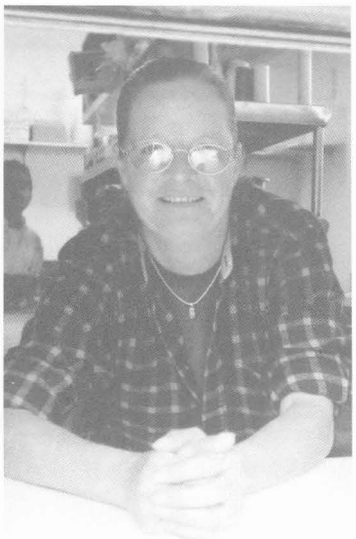


RASA GUSTAITIS

The Li'l Hut is only steps away from the wharf where fishing boats come in with their catch. "Everything's from somewhere else?" "That's right."

Later, at the city harbor department office, business manager Sue Lichtenbaum recalled: "In the '70s, when I worked for Bob's Seafood, 90 percent of the fish were local. You had to tell a customer when they weren't." Now few of the fish coming into the harbor are sold here. Squid caught by Morro Bay fishermen go to China for processing, albacore might go to American Samoa for canning. As for the local pismo clams, what was left of them disappeared in the late 1980s, along with abalone, when the sea otters began to recover and feast on their favorite foods. Until then, said harbor director Rick Algert, many restaurants served local clam chowder.

Did the Millers know that, I wondered, and if they didn't, would they have been disappointed if they'd found out? The next morning, I would hear Mayor Janice Peters tell the Coastal Conservancy, which was meeting in her town: "Morro Bay is primarily supported by the tourist industry, and the beloved and beleaguered fishing industry is part of what brings the tourists here."

Struggling to Survive

COMMERCIAL FISHING is "beleaguered" all along the coast, but its decline is especially hard on small towns that rely heavily on it. With prices for fuel and materials rising, gillnetting banned within three miles of the shore, severe restrictions on groundfish fisheries, and the burden of having to navigate a maze of regulations, many fishermen are finding that the cost of operation is too high for what they can earn. In Morro Bay, the industry has dwindled so much it no longer supports the storage, processing, and repair facilities the harbor used to provide.

Last August Algert wrote to State Resources Secretary Mike Chrisman: "If we let fishing businesses die or become any more economically unviable they will be supplanted by visitor serving uses, our harbor infrastructures will be lessened, and these unique parts of California life will be history."

Not that the community hasn't been trying to keep the industry alive. Fishermen's slip rents are kept low. The harbor department subsidizes them with lease income from other properties it holds on the tourist-oriented part of the waterfront. In 2004, when Driscoll's Wharf Seafood, Inc., operator of the city-owned wharf, went out of business, the city helped the Morro Bay Commercial Fishermen's Organization take on the lease and, with funding from the Coastal Conservancy, improved the wharf. In 1984, to prevent tourist businesses from pricing fishermen out of the working waterfront, citizens passed Measure D, a voter initiative that rezoned the northern waterfront for waterfront-dependent uses. (Existing restaurants and other businesses were allowed to stay.) There has recently been talk about modifying Measure D zoning because considerable space on the northern waterfront stands empty.

Part of California fishermen's problem is that they operate in market frameworks that have become obsolete. Scarcity of fish is a fact under the current regulatory environment, but the market structure doesn't allow fishermen to benefit from the higher values that scarcity could bring. For the most part, fishermen sell their whole catch at once, as farmers might a load of grain or other commodity. The lack of competition among buyers and markets leaves them little choice but to take the price they are offered.

"Our fishermen harvest pearls and are forced to sell their seafood products for the price of a shell," said Algert. "What is needed is innovative new thinking on markets to get this incredible fresh seafood to our California consumers and add price value to the fishermen. A transition must be made from high-volume low-end to low-volume high-end."

Commercial fishing in California declined for many years, largely because of overfishing and habitat damage. In the 1950s and '60s, up to 50 trawlers, 60–70 feet long, went for groundfish out of Morro Bay, wreaking havoc on bottom habitat. The federal government encouraged industrial-scale commercial fishing by offering low-interest loans. Regulation began only in the 1980s,

MARC KURTH

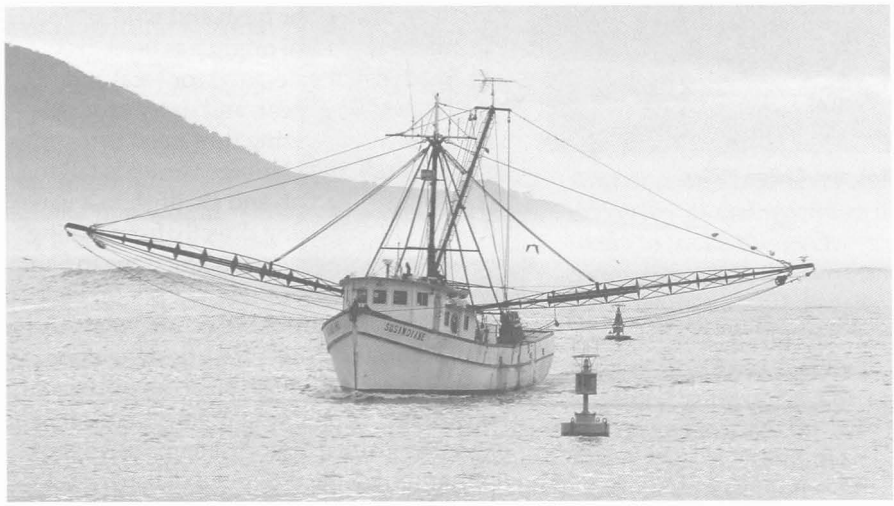
MARC KURTH

too late to prevent depletion of some groundfish stocks.

But many corrective measures have been taken in recent years and "things are looking up, generally," according to marine ecologist Rod Fujita of Environmental Defense. Some groundfish stocks are now rebounding and fishermen report that some populations are abundant. However, Fujita notes that only 23 of the 82 species of groundfish that are commercially exploited off the West Coast have been assessed, and that about a quarter of those were found to be overfished.

A federal buyout program has reduced the number of fishing vessels, enabling those that remain to get their trip limits. The Nature Conservancy is now negotiating with several of the seven federal bottom-trawl permit holders for the purchase of their groundfish permits and, in some cases, their vessels. It is also exploring a possible temporary lease-back, to help these fishermen to prepare for the transition.

The Nature Conservancy is eager to establish a long-term relationship with the central coast fishing industry and ports, said Chuck Cook, the conservancy's project director of coastal and marine affairs for California, partly because these fishermen agreed to the establishment of large no-trawl zones—3.8 million acres between Point Conception and Point Sur. The Pacific Fishery Management Council (PFMC) decided last June to establish these zones. They go into effect in May 2006, protecting some of the most richly diverse marine ecosystems along the California coast, as well as historic fishing grounds.



MARC KURTH

By agreeing to protect these areas, Cook pointed out, the groundfish fishermen agreed to close existing and potential fishing grounds in an area about the size of Connecticut. Now the Nature Conservancy intends to help create a more robust fishery and working wharf while at the same time protecting underwater habitat.

"The PFMC has taken many painful steps to conserve fish stocks," Fujita noted. At the state level, the Marine Life Management Act, "one of the best and most precautionary fishery laws in the world," according to Fujita, has led to reductions of nearshore quotas and permits to conserve nearshore fish species and ecosystems such as kelp forests.

These conservation measures may improve the prospects for fishermen in the future, but now they impose further hard-

MARC KURTH

Top: Morro Rock from Morro Strand Beach

Middle: A fishing boat on Morro Bay

Bottom: Fishermen at work on the Morro Bay docks

RASA GUSTAITIS

Bob and Celine Miller

ships. "Depleted fish stocks are no longer our problem here in Morro Bay," Algert says. "Most days we never even have a boat leave the harbor, since the regulatory regime doesn't let them fish." To survive, commercial fishermen must adapt to the current conditions and options.

With that in mind, the Fishing Heritage Group was formed early in 2005. A collaborative effort by Environmental Defense, the Nature Conservancy, fishermen, Central Coast harbors, and others, it is "creating a vision of selective fishing, catching lower volumes but bringing in much higher value," Fujita said. The goal is a sustainable local fishing industry that enables fishermen to make a living while protecting marine life and habitat and allowing the region's ports to continue processing and distribution.

Boat to Table

THE DEMAND for fresh and wild seafood products of local origin has been growing, much like the demand for local and organic produce, meat, and dairy products. Fishermen are realizing they need to tap into that demand. The Heritage Group is talking about marketing fish and shellfish in a variety of ways, including directly from fishing boats to consumers, as is being done in Santa Barbara and at Pillar Point Harbor on Half Moon Bay. They are thinking of "value-added" products that could be developed. Instead of sending fresh albacore overseas for canning, or shipping premium fish like black cod (sablefish) to Asian markets, they might prepare these delectable fish for sale to California consumers. To reinvent the local commercial fishing industry, a creative business plan based on sound market and business analysis will be essential.

The business model adopted by Mark Tognazzini and his family is an example of the kind of creative thinking that's needed. A commercial fisherman for 35 years, Tognazzini sells some of his catch directly off his boat, the *Bonnie Marrietta,* notifying his list of customers by e-mail every Thursday of his "Weekly Specials." He also features local fish on the menu of Tognazzini's Dockside Restaurant in Morro Bay, which he runs with his wife, Bonnie, and their family. They bought the restaurant in 2004. If you ask for the special, he is likely to come to your table with a logbook and look up who caught your fish and where. He invited fellow fishermen to decorate the restaurant's 23 tables with personal photos, placed under glass. The restaurant's back door opens onto the wharf. Diners are apt to see fishermen both inside and outside the place.

On the day I ate lunch there, John Lindsay, operations manager for the nonprofit Morro Bay Fisherman's Wharf, had stopped in for a cup of coffee and a chat. Tognazzini had just leafed through the Spring/Summer issue of *Coast & Ocean* and highlighted some lines in the "Fishwise" story, which stated that "some salmon fishers still use longlines." This is not true, Lindsay said, and Tognazzini agreed. "Salmon are all caught by single hook, except by Indians." *[True in California—not longlining but trolling is the hook-and-line method for salmon; some tribes use gillnets or traditional dipnets.—Ed.]*

There is no single formula for success, and most fishing communities attempting to make this transition will require financial assistance. A fisheries revolving loan fund (conceived of by Environmental Defense) for fishermen and their communities is in the works. The Coastal Conservancy and California Ocean Protection Council together have committed $101,000 towards its development. Initial capitalization of up to $2 million is expected to follow. To make sure that fishermen continue to have access to the city dock, the Nature Conservancy has offered to help pay part of the operating costs temporarily.

The hope is that commercial fishing can continue as part of the fabric of life in Morro Bay even with growing numbers of visitors and new residents—including retirees from the Central Valley and coastal metropolitan areas to the north and south—who come to enjoy the natural beauty and wildlife of the region. Morro Bay is a great place for birding. In addition to enjoying the wildlife, however, these new residents may also increase the demand for locally caught seafood.

Meanwhile, the city is continuing to improve public access to its waterfront. The latest project is Harborwalk, a new mile-long path that will link the waterfront's commercial retail and fishing area with the beaches surrounding Morro Rock. Funded in part by $500,000 from the Coastal Conservancy, it is to open on Memorial Day, 2006.

A million people now visit the Morro Bay waterfront every year. Soon more will come. If the fishing industry succeeds in making the turnaround to sustainability, visitors will be offered local seafood. The Millers might try the local albacore, boccacio, cabezon, or lingcod and discover new reasons to return. ■

Are We Ready in the Delta?

TWO OR THREE mornings a week I get up before dawn and go for a bike ride. My route takes me up into the East Bay hills above my home in Oakland, and it is unfailingly beautiful. Depending on the time of year, I may see dawn lighting up the office towers of San Francisco, fog lingering in the valleys of Contra Costa County, deer, wild turkeys, or California quail on the hillsides, or red-tailed hawks hovering over the ridgeline at sunrise.

My route also takes me over the Hayward Fault, part of a nearly continuous system of earthquake faults running from San Jose to Santa Rosa. Based on research since the 1989 Loma Prieta earthquake, the U.S. Geological Survey concluded that there is a 62 percent probability of at least one quake of magnitude 6.7 or greater, one that is sure to cause widespread damage, striking the San Francisco Bay region before 2032. In other words, a major quake is about twice as likely to happen as not to happen in the next 27 years.

I like to think of the Hayward Fault as my own, though I share it with millions of people. After all, my home is less than half a mile from it. It runs straight through the University of California, Berkeley, campus, Highway 13 is built along it, and it bisects Highway 24—one of the busiest commute corridors in the Bay Area—and the BART tunnel under the Bay. Over a million people in the East Bay get their drinking water from an aqueduct that runs through the Hayward Fault, and several critical high-voltage transmission lines run through it as well.

As the Winter 2004–05 issue of *Coast & Ocean* reminded us, life in California means living on the edge of all kinds of natural disasters: earthquakes, floods, fires, and landslides are all part of the state's geology and climate. Often these things occur in combinations: fire followed by landslide, or earthquake followed by fire. In the wake of Hurricane Katrina and the disaster in New Orleans, Californians have been reminded again of one of our most catastrophic nightmares: an earthquake that would destroy levees in the Sacramento–San Joaquin Delta.

SAM SCHUCHAT

On September 8, with much of New Orleans still under water, the *San Jose Mercury News* reported that "Scientists and state water experts have warned for more than two decades that a large earthquake or flood could burst holes in the fragile 1,100-mile network of levees crisscrossing the Delta from Antioch to Stockton." Our state capital, Sacramento, lies at the confluence of the state's two largest rivers. It is less than 20 feet above sea level and 90 miles from the ocean. Sacramento has a 100-year level of flood protection—the lowest level of protection for any large urban area in the nation. New Orleans had a 250-year level before Hurricane Katrina struck. Failure of levees in the Delta and around Sacramento would not only threaten the lives and destroy the property of the millions of people who live there, it would also cut off much of the water supply to urban southern California and to agriculture in the Central Valley.

Are we ready? I doubt it. Governor Schwarzenegger has asked the federal government for $90 million to improve some of the most critical levees in the Delta and the Central Valley. If granted, this would amount to a down-payment on the $1.3 billion in repairs officials say it will take just to bring the levee system up to basic standards, according to a *Los Angeles Times* report on September 19. And of course, sea-level rise driven by global warming is likely to make this even more difficult in the future. After every natural disaster, California ramps up its level of readiness, but there are still gaping holes. For instance, just a few weeks ago the *San Francisco Chronicle* reported that the city's fire hydrants use a different gauge hose connector than every other fire department in the region, which would make it difficult for firefighters from other cities to come to San Francisco's aid during a disaster.

There is still plenty to do to prepare for, and in some cases to prevent, disasters. In my neighborhood and in my office, the lesson of Hurricane Katrina seems to be: "After the deluge, you're on your own," at least for a while. We will be updating our earthquake kit soon. I hope our city, state, and federal governments will do the same.

—*Sam Schuchat*

COASTAL CONSERVANCY NEWS

BETWEEN MAY and September the Coastal Conservancy approved a variety of public access and habitat restoration projects along the coast and on San Francisco Bay. Most of these projects were made possible by Propositions 40 and 50, the park and resources bond acts approved by voters in 2002.

RESTORATION AT ORMOND BEACH

ANOTHER STEP toward an ambitious restoration goal was taken in August, when the Nature Conservancy, using $13 million provided by the Coastal Conservancy and the Wildlife Conservation Board, bought 276 acres of wetlands at Ormond Beach from the Metropolitan Water District of Southern California and the City of Oxnard. This property adjoins 265 acres of dunes and marshes that the Coastal Conservancy has owned since 2002.

The purchase moved forward a plan to restore much of the 1,000 or so acres of wetlands that once existed along this coastal stretch of Ventura County. The Coastal Conservancy has been working on this plan with the Nature Conservancy, wetlands scientists, local partners, and other public agencies, and has reserved funds for the purchase of at least 200 more acres. Restoration of 750 or more acres—about three-fourths of the wetlands that used to exist here—would be expected to result in a biological system with sufficient freshwater flows and tidal action to sustain its environmental health.

If integrated with neighboring coastal wetlands, including 1,500 acres at Mugu Lagoon, Ormond Beach would be at the core of southern California's largest coastal wetlands, stretching nine miles from Point Hueneme to Point Mugu.

The newly approved purchase will benefit fish, migratory birds, and six endangered and threatened species, including the western snowy plover and California least tern, which rely on the dune and marsh habitat. About 95 of the 276 acres are farmed and will continue to be leased for agriculture until wetland restoration can take place.

ISLA VISTA AND CAYUCOS BEACH STAIRWAYS TO BE REBUILT

IN ISLA VISTA, three stairways that have often been closed because of storm damage will be rebuilt with the help of $150,000 approved by the Conservancy in September. The stairways down a 40- to 50-foot bluff along Del Playa Drive at Escondido Pass, Camino del Sur, and Camino Pescadero provide access to highly popular beaches and surf spots. The County will contribute $136,000 of its own funding for the reconstruction, and will be further aided by an $80,000 grant from the University of California, Santa Barbara, Shoreline Preservation Fund. The County plans to transfer the stairways to the Isla Vista Recreation and Park District.

SAN LUIS OBISPO County will reconstruct five beach stairways that lead to Cayucos State Beach from the ends of First, Sixth, Eighth, Tenth, and 16th streets, using $150,000 approved by the Conservancy in September, as well as $75,000 of its own money. In 1983, the Conservancy provided the County with funding to build or improve ten beach accessways in Cayucos. Since then, heavy public use and exposure to the marine environment have taken their toll, and five of the accessways were found to need immediate restoration.

ISLA VISTA RECREATION & PARKS DISTRICT

This stairway at Camino del Sur in Isla Vista will be reconstructed.

CHRIS PATILLO

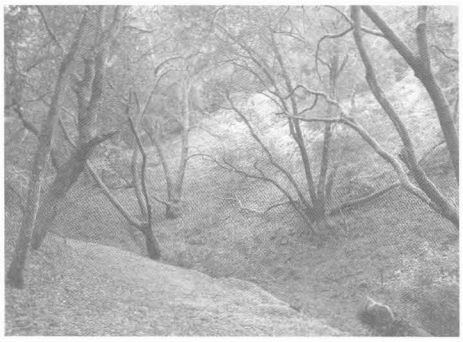
The grand opening of Union Point Park on the Oakland Estuary was celebrated on September 10, 2005. The Coastal Conservancy worked closely with the Port and City of Oakland and the nonprofit Unity Council to plan and build the park, which now provides bayfront access and recreational space to a part of the city severely lacking in such facilities.

MORE PACIFICA SHORELINE ACCESS

THE CITY OF PACIFICA will purchase a 2.17-acre property on the west side of Esplanade Drive, between Manor and Aura Vista Drives, thus acquiring 600 feet of blufftop above Esplanade Beach. The cost of the purchase is being shared equally by the City and the Coastal Conservancy. The California Coastal Trail will run on an easement on the property. A stairway to the beach may also be built.

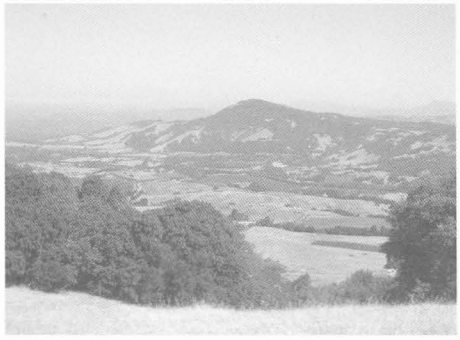
ADDITION TO PLEASANTON RIDGE PARK

A 106-ACRE ADDITION to Pleasanton Ridge Regional Park will protect scenic views and wildlife habitat and set the stage for greatly improved access to parklands in the Pleasanton-Dublin area. The East Bay Regional Park District expects to make the purchase using $400,000 from the Conservancy and $450,000 from Alameda County. The purchase of the property, part of a ranch owned by the Vinson family, is a step toward providing a northern entrance to the park, which is south of Dublin near I-580. The only current public trail access to Pleasanton Ridge Park is from its southeastern corner. The planned route of the Calaveras Ridge Trail, which is being developed to run between the Sunol and Las Trampas regional wilderness parks, passes through the Pleasanton Ridge parkland.



SUSAN CANALE

A wooded swale in Pleasanton Ridge Regional Park



View from the site of the proposed Sonoma Mountain Ridge Trail

SONOMA COUNTY AGRICULTURAL PRESERVATION AND OPEN SPACE DISTRICT

SONOMA MOUNTAIN TRAIL

THE SONOMA County Agricultural Preservation and Open Space District is working on final plans for a trail across the north slope of Sonoma Mountain, using $110,000 approved by the Conservancy in May. The trail, which begins at Jack London State Park, will traverse several properties that the District has strategically acquired and one 452-acre parcel owned by the County. When the trail is complete, users will enjoy a variety of terrain and spectacular views on foot or horseback. Docent-led tours of the Jacobs Ranch property are available now through LandPaths (www.landpaths.org).

The new trail will provide easy public access to parklands with diverse plant and animal habitat and wide-ranging views. Since its first acquisition in 1992, the District has protected 135 properties totaling over 65,000 acres by means of conservation easement and fee purchases. Sonoma County voters approved a 25-cent sales tax in 1990 to make such open space protection possible. *[See p. 28.]*

FORT BRAGG SHORELINE ACCESS

IN MAY, THE Conservancy approved $4.2 million to the City of Fort Bragg for the purchase of part of the 413-acre site of the closed Georgia-Pacific sawmill. The City will use the funds to buy 35 acres of the site for parkland. Georgia-Pacific donated to the City about 38 acres, valued at $3.3 million and containing the property's whole shoreline and most of Fort Bragg's waterfront. Georgia-Pacific closed the mill in 2002, after more than 100 years of operation, and has since been working closely with the City, the Conservancy, regulatory agencies, and the local community on the property's reuse. The Coastal Trail will run the length of the blufftop along a 100-foot-wide trail corridor. It will link Glass Beach, to the north, to Pomo Bluffs Park, to the south. Both of those properties were acquired with Conservancy funding and strong community support. Environmental remediation must be completed on parts of the property to be acquired by the City before the land can be opened to the public.

MENDOCINO COUNTY BEACH ACCESS

ACCESS TO MENDOCINO County beaches is expanding. In September the Conservancy approved $240,000 to the Mendocino Land Trust to design and plan 15 new accessways and to continue to manage three existing trails to beaches. In May, it approved $140,000 to the nonprofit Westport Village Society and $100,000 to the Redwood Coast Land Conservancy for projects that will make it much easier to reach the surf at Westport and Gualala.

The Village Society will build a stairway to the beach along the bluff face of the Westport Headlands, about 15 miles north of Fort Bragg. To reach this beach now, people scramble down a steep, rough trail while grasping a rope that dangles from the blufftop. Small boats have been winched up and down the bluff on a launching chute. The new stairway will also be built to allow small boats to be raised and lowered. Also included in this project are a wheelchair-accessible scenic overlook and a 660-foot blufftop trail, part of the California Coastal Trail, along Highway 1. In 2000, the Conservancy provided the Village Society with $727,000 to buy the nine-acre headlands. The purchase prevented private development of the property, reserving it for these public access improvements.

Meanwhile, the Redwood Coast Land Conservancy will improve and maintain three beach trails about three miles north of Gualala. Two of the trails begin along Highway 1 near Bourne's Landing. One leads to Cook's Beach, the other to a blufftop overlook. The land conservancy will grade the trails, strengthen them with base rock, and install cable steps down to the beach. The third trail, which leads from a parking area along Highway 1 to the beach at the mouth of St. Orres Creek, will be realigned and improved. A cable step ramp will be installed for the 15-foot descent from the blufftop. Construction is expected to begin later this year, with the goal of completing the trails in about a year. New signs maintained by land conservancy volunteers will direct beachgoers to the trails.

DERELICT FISHING GEAR REMOVAL

A $300,000 GRANT to the U.C. Davis Wildlife Health Center's SeaDoc Society has launched a pilot program to remove derelict nets, lines, pots, and other gear that lies on the seafloor, gets caught on rocky reefs, or floats in the water. *[See p. 17.]*

Looking south from Westport Headlands

SHEILA SEMANS

LAND OF SUNSHINE:

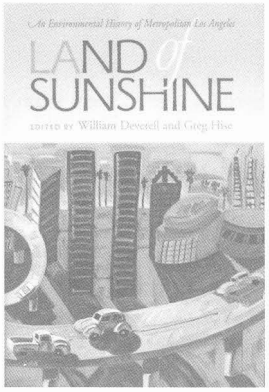
An Environmental History of Metropolitan Los Angeles, *William Deverell and Greg Hise, ed. University of Pittsburgh Press, 2005. 360 pp., $34.95 (hard cover).*

THIS INCISIVE, DIVERSE, and illuminating collection of writings compiled by William Deverell and Greg Hise sheds new light on Los Angeles' relationship with its natural landscape as it has evolved over time.

In "A Garden of Worldly Delights," Douglas C. Sackman presents a theme that runs through the book: how promoters marketed a semi-arid region as a lush, fruited, well-watered garden paradise to foster the growth of an export-oriented agricultural industry and encourage tourism and migration. Attempts to superimpose this vision of a lush paradise onto Los Angeles resulted in the destruction of much of the region's native habitat and the depletion of its water resources.

Essays by L. Mark Raab and Paula M. Schiffman discuss the natural and cultural landscape before European settlement. Raab focuses on changes in the way scholars have viewed the local indigenous people and their relation to the environment. Until the 1960s, the prevailing view was that California was "a natural hunter-gatherer paradise," and that its people had remained primitive. This view later shifted to include evidence that the Chumash, Gabrieleno, and other peoples had skillfully managed and controlled lands by selective burning, pruning, and propagation of plants. Now there are indications that this too was an oversimplification. New evidence of shifts in diet, declining health trends, and serious climatic variations suggest that the relation of California Native Americans to the environment likely was much more complex than has been thought.

Schiffman, in "The Los Angeles Prairie," discusses the loss of the prairie ecosystem that once covered the region's plains and valleys. While some areas of chaparral, coastal sage scrub, oak woodlands, and riparian corridors still survive, the broad flat prairies with all their spring wildflowers have been completely lost—first plowed under, then paved over and replaced by an "urban woodland" of ornamental trees and shrubs.



Several writers document the growth of Los Angeles in the late 19th and early 20th centuries, and the concomitant sacrifice of the natural environment and human health (or certain people's health) to the push for growth and prosperity. Daniel Johnson and Christopher G. Boone both look at environmental justice issues relating to the industrial development of Los Angeles in the early 20th century. Johnson considers the unequal impacts of industrialization, when noxious slaughterhouses and gas plants were sited in the working-class East Side of the city despite residents' objections. Boone documents the Regional Planning Commission's use of zoning in the 1920s to concentrate industry, and therefore toxic sites, in poor and minority communities of eastern Los Angeles County.

In "Who Killed the Los Angeles River?", Blake Gumprecht argues that the U.S. Army Corps of Engineers was not to blame. By the time the Corps built its flood-control project from the late 1930s to the late 1950s, he maintains, the river was already almost dead. Its destruction was much "more gradual and complex, and flood control officials were little more than undertakers, closing the coffin on (the) river. . . ." Jared Orsi looks at the role that the politics of growth played in determining the nature of the flood-control system engineers designed and built over the region's rivers and streams.

John McPhee's "Los Angeles Against the Mountains," excerpted from *The Control of Nature,* tells in great and fascinating detail of the struggle to contain the San Gabriel Mountains by constructing 120 debris basins to capture the "rivers of boulders" that tumble down. By 1989, McPhee notes, Los Angeles County was spending approximately $60 million a year to clean out the debris basins.

In "Changing Attitudes toward Animals among Chicanas and Latinas in Los Angeles," Unna Lassiter and Jennifer Wolch discuss their interviews with 17 women who were either immigrants or first-generation Latinas. They found that after living in Los Angeles, these women, many of whom grew up with domestic animals raised mainly to provide food, came to see both domestic and wild animals as creatures requiring protection. In these communities, many farm animals are now kept as pets, links to a rural past in which they were an integral part of the home. "Chickens, roosters, rabbits, sheep, and goats, living in tiny back yards, or even on the apartment balcony, are an increasingly common sight in Los Angeles' dense Latino neighborhoods, especially those with large shares of immigrants," write Lassiter and Wolch.

Robert Gottlieb closes the book with an essay on how evolving attitudes toward water and food indicate a changing environmental awareness in Los Angeles.

Land of Sunshine is an important contribution to the understanding of the environmental history of the Los Angeles region and the continuing evolution of its relation to nature. The book's great strength is the depth and diversity of perspectives and the resulting rich blend of viewpoints.

—*Christopher Kroll*

HUMPBACK WHALE BREACHING OFF MORRO ROCK, AUGUST 3RD, 2005

"A few people have said they believe this is a fake. I have been told things like, 'It can't be real, I've never seen anything like it.' Well the truth is, it is real! It was just as hard for me to believe my eyes that day. There were five witnesses to this event on our boat."

—photographer Gregg Blasingame

Coastal Conservancy

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