California Sea Grant Annual Report

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and private sectors, combining research, education,
and outreach for public service.
It is a national network of universities meeting
changing environmental and economic needs
of people in our coastal, ocean,
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introduction...

Russell A. Moll, Director

This annual report represents achievements from research and outreach activities undertaken by California Sea Grant from March 2000 through February 2002. The purpose of the report is to highlight results that will inform the public, and provide a record of our accomplishments for individuals in government, industry and the academic community.

California Sea Grant is the largest of 30 national programs located in our Great Lakes and coastal states. While our headquarters are located at the University of California, San Diego, the program serves the entire state through a network of university-based research and outreach.

Our primary mission is to expand the base of scientific knowledge necessary to promote the sustainable use of California's coastal and marine resources. In this role, California Sea Grant supports research to help stakeholders solve the challenges of a modern world, and public outreach and education to encourage stewardship and conservation.

I arrived as the new director of California Sea Grant in the fall of 2000. At that time the state was flush from a rapidly growing economy, and enjoyed what appeared to be limitless resources and potential. However, since 2001, we have been repeatedly challenged by unforeseen local, regional, national, and world events. These events have given us pause to reflect on the conduct of our daily lives. As coastal residents, we must now add issues such as security, environmental protection, and safety to the list of previous challenges that have faced us. The desire to make informed decisions about each of these issues inspires us to learn more about our environment.

Accordingly, I believe the relevance for a program such as California Sea Grant continues to grow. In a faster-paced world filled with surprising events each day there is, more than ever, a need for credible information to produce an informed public. This is a central tenet of our mission—***to support research and outreach concerning our marine environment***. At the same time, if we are to have a vibrant and resilient economy, and yet conduct commerce in an environmentally responsible manner, we must seek to further our knowledge and understanding of where we live and work.

This 2000–2002 report provides the reader with a glimpse into some of the issues addressed by California Sea Grant. Topics such as preserving essential habitat to support fish populations, combating unwanted invading organisms, tracking coastal water quality and sediments, and seeking novel marine compounds remain a hallmark of the program.

I encourage you to learn more about California Sea Grant and our achievements through this report. I trust you will be intrigued by these findings, and that you will endeavor to join with California Sea Grant in becoming better and more enlightened stewards of our precious marine resources.

Russell A. Moll
Director, California Sea Grant College Program

Mapping Essential Fish Habitat Along the State's Continental Shelf

In the summer of 2002, California Sea Grant scientists produced a comprehensive set of high-resolution digital images of fish habitat along California's continental shelf. The maps, among the most detailed available to date, depict small-scale features on the seabed—pinnacles, rock reefs, boulder piles and crevices—that may provide key feeding, breeding and spawning grounds for species of management concern, including depleted rockfish.

Protecting fish habitat has become a focal point of fisheries management in recent years, largely because traditional emphases on stock assessments, total-allowable catches and minimum-size restrictions have failed to prevent the depletion of some stocks. California Sea Grant funded this project with the goal of assisting fishery biologists in identifying key benthic habitat areas. Such maps will help both state and federal agencies meet new fisheries management mandates.

The cornerstone of the project was to exploit existing data, including previously proprietary industry data, on the shape and composition of the seabed. Most of this data was provided by consulting companies to the oil industry, and to a much lesser extent, by telecommunications companies and government. Oil companies use acoustic and seismic imaging to prospect for oil reserves while telecommunications companies image the seabed before laying fiber-optic cables. The bulk of the industry data spanned nearshore waters between 10- and 200-meters deep. This is a region of intense interest because of a recent California mandate to develop species-by-species management plans for nearshore rockfish. Some of the data also covered deeper waters of the continental shelf and slope, and the scientists were able to supplement this data with existing geologic maps produced by the U.S. Geological Survey and the California Division of Mines and Geology. This deeper data is becoming increasingly important, too, since fishing efforts tend to shift to progressively deeper waters as nearshore stocks are depleted. This pattern is particularly true for certain rockfish species.

"One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States."

—Magnuson-Stevens Act of 1996

Black rockfish, *Sebastes melanops*, in the Monterey Bay National Marine Sanctuary. Maps of essential fish habitats will help state and federal regulatory agencies meet mandates to protect rockfish species and their habitats. Photo: Kip Evans, NOAA archives

National Sea Grant funded marine geology professor Dr. Gary Greene of Moss Landing Marine Laboratories to collect, compile and interpret reams of acoustic and seismic images covering hundreds of thousands of square kilometers of the seafloor in areas around Point Conception, Santa Maria Basin, Santa Barbara Channel, Santa Cruz Basin, Bodega Bay and Eel River. Acoustic and seismic images do not always uniquely identify what is on the seafloor. And, although

Sonograms of the Seafloor

On land, wildlife habitats are usually, and obviously, defined by flora, climate and altitude. In the inky depths of the sea, habitats are delineated quite differently—by substrate type, water depth and seafloor geomorphology.

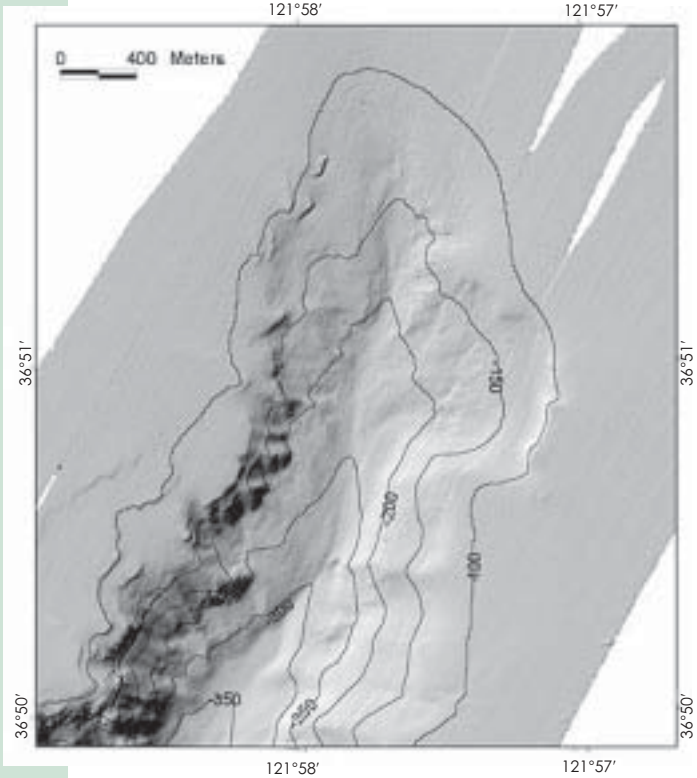
Since seawater covers these habitat areas, how do scientists "see" what is on the bottom? Right now, techniques rely on bouncing sound waves off the seafloor and "listening" to their echoes.

The modern techniques for imaging the seafloor began in the early 1990s in Monterey Bay National Marine Sanctuary, as NOAA, NOAA Fisheries, the U.S. Geological Survey and others began characterizing the complex canyon topography and associated rockfish habitats at the sanctuary.

In the mid-1990s, Sea Grant, the Monterey Bay National Marine Sanctuary and the California Department of Fish and Game supported the newly formed Center for Habitat Studies at Moss Landing Marine Laboratories to characterize fish habitats around the Big Creek Ecological Reserve. By the late 1990s, the Seafloor Mapping Laboratory of California State University was established.

More recently Sea Grant, in collaboration with the California Department of Fish and Game, has funded scientists to digitize and interpret geophysical data collected by oil companies, data that up until recently were proprietary and not available for scientific study.

Why are the maps of use? Many reasons. Top among them: the California Department of Fish and Game Commission in September of 2002 adopted the state's first Nearshore Fisheries Management Plan for 19 species of finfish, most of them rockfish. The maps that are being produced will help resource managers identify areas that support these species. There is also a federal mandate to protect "essential fish habitats."



Multibeam bathymetric data help scientists distinguish steep rocky ledges and gentler sedimented slopes in Soquel Canyon in the Monterey Bay National Marine Sanctuary. The contours demark lines of constant water depth. Imaging: Center for Habitat Mapping, Moss Landing Marine Laboratories

The Essential Fish Habitat mandate represents a new recognition by Congress, the fishing industry, conservation groups, and the general public that habitat quantity and quality is critical to the health and productivity of fish populations.

—National Oceanic and Atmospheric Administration

"Fish populations around the country are experiencing the effects of lost coastal wetlands and seagrass beds, dammed rivers, contaminated sediments and diminished water quality. The essential fish habitat provisions of the Magnuson-Stevens Act were developed to prevent future habitat problems before the finfish and shellfish that depend on healthy habitats suffer further declines."

—Bill Hogarth, NOAA Fisheries Assistant Administrator

bathymetric readings produce photographic-like images, backscattered images from which substrate is inferred do not provide a readily apparent visualization of what is being imaged. Backscattered images look more like sonograms or ultrasound images and thus require some subjective interpretation and a deep knowledge of how different rocks scatter sound or propagate seismic waves. A mud-bottomed area, for example, might appear as a black patch, because mud absorbs sound waves, Greene explained. Boulders, in contrast, scatter sound in a pattern characterizing their size. Greene spent a significant part of his time not only interpreting images but also working out inconsistencies in overlapping data and using existing geological maps of the seabed to corroborate, when possible, his interpretation of substrate type.

Once benthic substrates have been mapped, it becomes relatively easy for biologists to begin making assumptions about the types of animals and plants living in a region. Tiger rockfish, for example, are known to congregate in rock crevices. Halibut prefer sand-bottomed areas.

In addition to funding Greene to compile existing industry and government data, National Sea Grant supported a second closely related mapping project, conceived with the idea of filling gaps in existing data. This second project, led by professor Dr. Rikk Kvitek of the Seafloor Mapping Laboratory at California State University, Monterey Bay, involved conducting multi-beam bathymetric surveys of nearshore habitat areas around Santa Monica Bay, La Jolla Canyon, Santa Barbara and Catalina islands, Bodega Bay and Point Lobos. These areas were selected as high-priority sites by participants at a workshop of the California Marine Habitat Mapping Task Force held in 2000. In all, about 100 square kilometers were surveyed and mapped.

Photo: National Marine Fisheries Service

The set of maps produced by these two Sea Grant projects have been formatted for compatibility with GIS-mapping software and will soon be available on compact disk and on the Internet for public downloading. In these readily available, user-friendly forms, the maps' applications are nearly endless.

From a broad perspective, they have already proven to be of immediate use in helping NOAA Fisheries meet a 1996 amendment to the Magnuson-Stevens Act requiring the agency "to minimize to the extent practicable adverse effects of fishing on essential fish habitat." NOAA Fisheries has also used the maps to help it identify high-relief seafloor features that may be supporting populations of federally protected endangered white abalone.

The California Department of Fish and Game has used the maps to help guide its submersible on fish surveys, comparing fish abundance and diversity within and outside no-fishing zones. Fish and Game may also use the maps to help it identify candidate sites for inclusion in a statewide network of marine protected areas, as required under California's Marine Life Protection Act of 1999. The maps are also suitable for inclusion in the state's Habitat Maps Series, a comprehensive inventory of essential fish habitats off California, resolved at a courser scale than that of the Sea Grant maps.

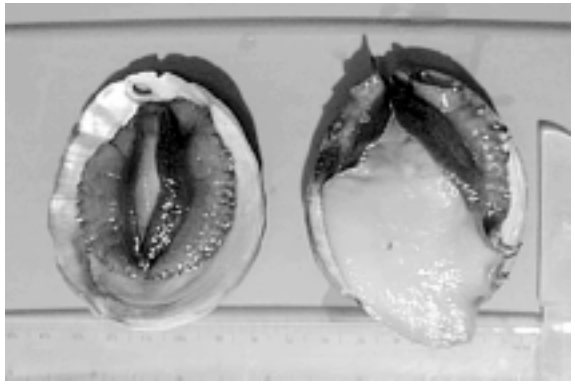
Withering Abalone Disease Spreads to Northern California

During the last fierce El Niño in 1997–98, a deadly disease swept through California's abalone farms, destroying $1.5 million worth of abalone at the state's two largest farms. Despite a return to normally cool ocean water temperatures, this same lethal disease appears to be marching north, into waters once thought to be safe havens for both wild and farmed abalone, according to a recent Sea Grant project led by professor Carolyn Friedman of the University of Washington in Seattle. At the time of the study, Friedman was a senior fish pathologist with the California Department of Fish and Game and researcher at the University of California at Davis.

The apparent spread of withering syndrome, Friedman says, raises concerns that another warm water event, such as another strong El Niño, could trigger an outbreak in beds north of San Francisco, home of the last healthy remnant abalone populations in the state and the only areas still open to recreational abalone diving.

Based on a 1999–2000 survey of beds in Central and Northern California, the bacterium that causes withering syndrome has reached as far as Van Damme State Park in Mendocino County and Crescent City near the Oregon border, the northernmost extent of the bacterium on record. None of the abalone from these two survey sites showed clinical signs of disease, but the mere fact that they harbor the infectious bacterium means that environmental stress—lack of food or balmy seawater—sets the stage for full-blown disease. The disease has already moved as far north as Point San Pedro in Pacifica. The northernmost extent of the disease previously was Cayucos Point in San Luis Obispo.

Withering syndrome is a lethal rickettsial-like infection caused by the bacterium *Candidatus Xenohaliotis californiensis*. Through a mechanism not yet fully understood, the bacterium attacks the lining of an abalone's digestive track, obstructing the production of digestive enzymes. Unable to digest what it has ingested, an abalone catabolizes, or consumes, its own foot muscle, hence the disease's name. Even while an abalone slowly starves, it continues to spread the bacterium via its feces. Wild abalone can thus spread disease to abalone farms circulating seawater through their tanks.



The abalone specimen on the left has withering disease. Note the severe atrophy, or withering, of its foot muscle. The specimen on the right is healthy. Photo: California Department of Fish and Game

Hundreds of thousands of abalone were destroyed or killed because of withering syndrome during the 1997–98 El Niño. It and another infection, caused by a South African worm, led to a dramatic drop in production; from 292,000 pounds in 1996 to 162,000 pounds in 1998. Production is still below its 1996 peak. In 2001, about 230,000 pounds were harvested, worth $3.6–$4 million.

The bacterium's newfound presence in northern waters also poses a threat to the health of wild beds. An epidemic in the 1980s decimated black abalone beds throughout Central California, with mortality rates hitting 99 percent in some areas. The combination of disease and severe over harvesting of the state's seven native abalone species eventually led to a moratorium on all commercial abalone fishing and, because stocks do not appear to be reviving, to progressively stricter limits on recreational abalone diving.

What has caused the bacterium's spread is unknown; but, Friedman said, outplantings or aquaculture might be to blame. Both Crescent City and Van Damme received outplantings of abalone seed, a well-intentioned effort to rebuild depleted beds carried out before scientists discovered the disease is caused by a water-borne bacterium. Crescent City is near an outfall for an abalone farm.

The Abalone Farm may have as many as 2 million abalone growing in concrete tanks along the coast. The company is working with scientists to develop oral antibiotic therapies for treating withering syndrome. Photos: Ray Fields, The Abalone Farm, Inc.

"We were very excited about working with Sea Grant on this project," said Ray Fields, president of The Abalone Farm in Central California, the nation's largest abalone producer. "We lost half a million abalone in the 1997–98 El Niño. It was a significant loss."

"Because of this Sea Grant research, there is now a treatment for the bacterium that causes withering syndrome, antibiotics administered in abalone feed," Fields said. "It has been a great collaboration."

The Abalone Farm donated abalone for experiments and allowed research to be conducted at its facility.

In terms of curing the disease, antibiotics are showing promise in cultured abalone. In an ongoing Sea Grant project, Friedman is collaborating with The Abalone Farm in Morro Bay to develop an antibiotic treatment put in abalone feed. They have shown that a two-week treatment of oxytetracycline (an antibiotic that already has FDA approval for use in aquaculture) protects an abalone for the duration of its culture cycle. In other words, farms have to give an abalone antibiotics only once in its life.

As treatment for farmed abalone continues to be developed, scientists are also looking to understand the conditions in the natural world that put wild abalone at risk. Stress is believed to lower abalone's resistance to disease. The main sources of stress in an abalone's life are warm water (abalone thrive in colder waters) and lack of food. El Niño events stress abalone on both fronts, since abnormally warm waters also kill kelp, their main food.

To better understand these stresses, Sea Grant has funded Friedman, in collaboration with researchers at UC Davis, to identify the connection between diet, water temperature and withering syndrome. The scientists' preliminary results show that warm water plays a much greater role in triggering disease than does extreme reduction in food, even starvation. Abalone infected with the bacterium and then starved did not develop disease, while those placed in warm-water tanks did. If the withering syndrome bacterium continues to spread, global ocean warming or a series of intense El Niño events could truly imperil the survival of wild abalone in California, Friedman said.

Aquatic Invader Appears Free of Dangerous Human Parasite ... Future Outbreak Possible

In 1992, shrimp trawlers in South San Francisco Bay hauled up the first mitten crabs on the West Coast. Since then, the crabs have spread like wildfire throughout the Bay–Delta, clogging fish screens at water intake stations and injuring fish in salvage tanks.

States like Oregon and Alaska are now on high alert, worried mitten crabs will burrow into the Northwest's economy next. So far, however, only one mitten crab has been identified outside the Bay–Delta area. In 1998, a male Japanese mitten crab, a close relative of the Chinese mitten crab, was pulled from the Columbia River in Oregon, fanning concerns of an alien invasion.

The Chinese mitten crab is native to estuaries and creeks in the Yellow Sea in China and Korea. Besides its furry pinchers, which earn it its sobriquet, it is a nondescript brown crab—about 3 inches in diameter. Photo: Lee Mecum, California Department of Fish and Game

Although notorious for clogging pumping stations, eroding levees and stealing bait, the Chinese mitten crab poses a perhaps equally significant, albeit less recognized, human-health threat as a host for a group of parasites known as lung flukes. In this project, completed in the spring of 2002, California Sea Grant funded marine researchers to search for evidence of these potentially dangerous parasites in the San Francisco Bay–Delta. A second part of the scientists' research looked at whether all requisite hosts for the flukes are present in sufficient abundance and distribution to sustain a future infestation.

Flukes come in Asian and North American varieties and can be acquired by eating raw or undercooked infected mitten crabs (*Eriocheir sinensis*). People infected with flukes may develop tuberculosis-like symptoms, resulting in permanent lung damage. The parasites can also migrate into the brain. Fluke infections are very common in Asia, where fresh mitten crabs, eaten raw, are a delicacy.

None of this would be such a serious concern—and wildlife officials could focus on dealing with the crabs' ecological consequences in the area—but for the fact that these furry-clawed crustaceans are a prized culinary treat within immigrant communities in San Francisco and Los Angeles. Despite prohibitions on their transport and sale, there is a flourishing underground market in live mitten crabs. In addition, it is legal, with a fishing permit, to recreationally trap and eat mitten crabs.

Because of this, health officials have expressed concern about the possibility of mitten crabs introducing Asian lung flukes or spreading existing North American flukes. This concern was heightened when fishermen began suggesting that the California Department of Fish and Game open a commercial fishery for the lucrative, and abundant, mitten crab.

The purpose of this Sea Grant project was to search for lung flukes in Bay–Delta mitten crabs and crayfish, the primary intermediate hosts for both Asian and North American lung flukes. Because freshwater gastropods are the first host, a second emphasis was to sample the region's snail populations. Mammals, including humans, are the final host for flukes.

To evaluate the health threat, Sea Grant marine researchers, led by Dr. Jenifer Dugan of the Marine Science Institute at University of California, Santa Barbara, collected more than 900 mitten crabs during the crabs' breeding season from the North and South bays, the Tracy Fish Collection Facility and several South Bay creeks. They also collected specimens from Coyote Creek during the crab's downstream breeding migration. Adults were preferentially collected

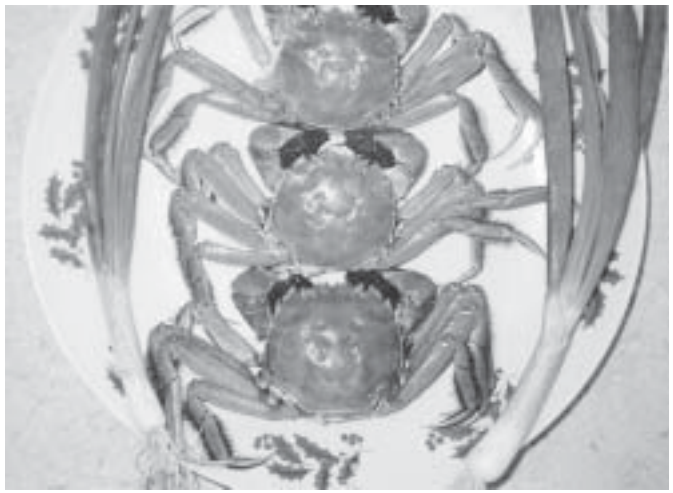
because it is older individuals that have the greatest likelihood of acquiring parasites.

All crab specimens were dissected, and their muscle tissue, gills and digestive glands were then microscopically examined for encysted larvae of lung flukes. None of the crabs were found to harbor evidence of lung flukes, either Asian or North American. More than 400 adult crayfish were similarly examined with the same result. None of the crustaceans showed any signs of fluke infestation.

This finding is considered statistically significant, not an artifact of a small sample size, because of the high rate of infection in endemic regions. In an infected waterway, 20 to 80 percent of adult mitten crabs would be expected to harbor flukes. Even commercially sold mitten crabs can have high rates of infection. In one random sample of 85 mitten crabs from markets in Seoul, Korea, for instance, about 12 percent carried flukes. Because absolutely no trace of fluke parasitism was found in the Bay–Delta crustaceans, the scientists believe that the chance of getting a fluke infection from a mitten crab is, at present, negligible.

"The Centers for Disease Control told health officials that California should assume that the lung fluke could be present at any time because the risk is present at all times."

—Susan Webb, chair of the multi-agency Mitten Crab Management Control Committee



Mitten crabs are a delicacy in Asia. Photo: Johnson Wang of the California Department of Water Resources

In terms of future risk, however, the news was not as good. The researchers' survey of snail populations showed that in every major geographical region of the Bay–Delta, there is at least one abundant snail species that could serve as a fluke host. These species, they showed, are also eaten by crabs and crayfish, meaning that trophic transmission of flukes is possible. Their conclusion: a future outbreak is possible. All requisite hosts are present in sufficient abundance and distribution for transmission and spread of a fluke infestation.

How would such an infestation come about? Flukes could be introduced through ballast water discharges of infected eggs, through infected juvenile snails or infected juvenile mitten crabs, or through the importation of infected feral or domestic mammals: dogs, cats, foxes, raccoons or possums. It is also possible that infected people, who excrete fluke eggs in their feces, could introduce or spread flukes, the scientists reported.

The scientists recommended monitoring parasitism in mitten crabs in the Bay–Delta and developing a risk-assessment model based on the size of the mitten crab population and on infection rates of people living in the Bay area.

Hoards of mitten crabs clog a fish salvage system, requiring workers to drain the tank. Photo: U.S. Bureau of Reclamation

Innovation Benefiting Sturgeon Aquaculture Industry

In recent years, Stolt Sea Farm California, LLC and other sturgeon farms stopped the once widespread practice of replenishing brood adults with wild-caught sturgeon. To look at whether the farm—and the industry as a whole—might be headed toward a genetic bottleneck, California Sea Grant supported a study led by Dr. Bernie May of the University of California at Davis.

May and his Sea Grant trainee examined the genetic diversity of progeny from the farm's brood adults. The research showed, among other things, that there were large genetic differences within each of the four year classes of sturgeon studied, meaning that in-breeding is not an immediate concern.

A farmed white sturgeon on ice. Photo: Stolt Sea Farm California, LLC

To prevent inbreeding at white sturgeon farms, Sea Grant researchers, led by Dr. Bernie May of the University of California at Davis, have mapped the pedigree structure of a commercial sturgeon brood stock. The geneticists' work, which was completed in 2001, opens up the possibility of selectively breeding sturgeon for superior caviar quality, larger size, better feed-conversion rates and disease resistance.

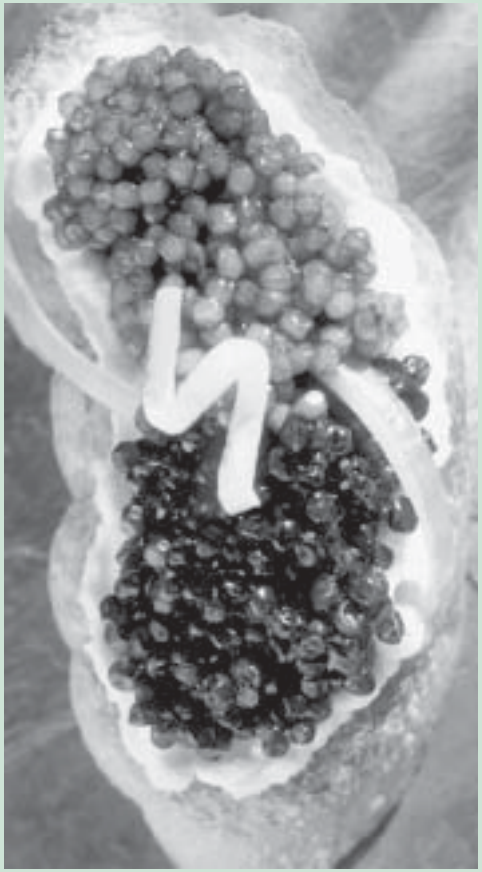
Such selective breeding strategies would greatly benefit California's commercial sturgeon farms, already among the most productive in the nation, by allowing them to further capitalize on a confluence of international factors now favoring the expansion of the domestic farmed-caviar industry.

The primary driving force behind this expansion has been the dramatic collapse of wild sturgeon stocks in the Caspian Sea region—the cradle of the world's specialty beluga and osetra caviars. All the region's sturgeon stocks are now listed as in danger of extinction. With caviar shortages and efforts to ban the exportation of some Russian caviars, farmed caviar has emerged as a competitively priced—and tasty—alternative to wild-caught varieties. Even gourmets, who compare farmed white sturgeon caviar to osetra, have been won over.

California Sea Grant can take partial credit for establishing the scientific base on which the rapidly expanding sturgeon industry has been built. Our involvement began in 1978 when Drs. Wallis Clark and Serge Doroshov of UC Davis were funded to develop a prototype sturgeon hatchery for white sturgeon. Their research involved what now seems routine: they collected wild sturgeon from the San Francisco Bay area, figured out how to transport them in aerated tanks, then how to acclimatize them to freshwater tanks, and finally how to induce gamete production. A series of projects led by Doroshov and others at UC Davis focused on understanding and then manipulating female sturgeon reproduction. From a commercial standpoint, this work was of paramount importance for the obvious reason that caviar is roe, and only females produce it. Consider too that it takes wild white sturgeon 14 to 30 years to reach full sexual maturity, and it becomes readily apparent that manipulating female reproduction has been key to creating the sturgeon industry.

A beluga sturgeon, traditionally the source of the world's premier caviars. Photo: Dr. Robert Stevens, U.S. Fish and Wildlife Service

For this reason, many of Sea Grant's research projects have focused on developing techniques for inducing spawning, accelerating sexual development and ensuring high ovulation and fertilization rates. As endocrinology progressed, other issues were in turn addressed. Sea Grant researchers, for instance, have studied the nutritional needs of captive sturgeon, their oxygen requirements and their rates of ammonia and carbon dioxide production. Other projects focused on eradicating disease by developing antibody tests for the detection of the white sturgeon iridovirus and by monitoring the environmental fate of antibiotic residues in wastewater, a project that streamlined FDA approval of antibiotic baths for sturgeon. All told, it would have been much more difficult, if not impossible, for the sturgeon aquaculture industry to get off the ground were it not for Sea Grant and the 13 projects it has funded on sturgeon aquaculture over the last 24 years.



Farmed white sturgeon caviar has become a popular alternative to wild-caught specialty caviars from the Caspian Sea region. The severe depletion of wild stocks is increasing demand for farmed caviar. Photo: Stolt Sea Farm California, LLC

Today, California is the only state in the nation that raises sturgeon for commercial caviar, though other states do raise sturgeon for meat. In 2002, California produced about 5.5 tons of farmed caviar, representing about 5 percent of the total caviar consumed in the United States that year. More impressive, however, is the upward trend in caviar production. From 1999 to 2002, production has increased about 50 percent a year.

In their most recent Sea Grant project, May and former Sea Grant Trainee Jeff Rodzen, now a forensic specialist at the California Department of Fish and Game, identified a set of genetic markers that allowed them to identify or "fin print" individual sturgeon and to determine the mode of inheritance. The most immediate use of these markers was in determining kinship relationships among brood adults at Stolt Sea Farm in Sacramento, the state's largest

producer of farmed caviar. The markers were also used to evaluate the genetic diversity of the brood stock's offspring, an important issue since the farm replenishes its brood stock with the brood stock's progeny. May and Rodzen's research has confirmed that the farm's breeding strategy conserves genetic diversity and that it does not need to replenish its gene pool with wild-caught sturgeon.

The genetic markers developed in this project may provide other lasting benefits. For example, the markers could potentially help farms eradicate disease. It is suspected that resistance to sturgeon herpes virus, for instance, is genetically conferred, as is susceptibility to white sturgeon iridovirus. Both viruses are lethal in young fish and have caused massive losses at sturgeon farms.

In a series of experiments, which focused on simpler traits, May and Rodzen sought to identify those characteristics that are inherited and those that are more highly influenced by environmental factors such as diet. In particular, they looked at the degree to which body size (weight and length) is correlated with dam and sire body size. They also examined a variety of caviar characteristics, including weight, grade, color, firmness and yield.

Their work has shown that adult body size, not surprisingly, has a strong genetic link, but that most of the coveted caviar traits are not obviously influenced by genetics. Although caviar yield was shown to be somewhat linked to the weight of the female, which in turn is a function of ancestry, caviar characteristics such as grade and color showed no bearing on bloodlines.

Even though geneticists were unable to discern a genetic link to caviar quality, Peter Struffenegger, general production manager at Stolt Sea Farm California, is convinced that such a link exists. Perhaps, he said, a complex set of genes work together to orchestrate caviar traits. He theorizes that it may take studying a large number of sturgeon—only about 100 were studied in this project—to discern the genetics behind prized caviar.

With May and Rodzen's markers, scientists and fish farmers can unlock the genetic basis of superior caviar. In the past, Struffenegger explained, if a female produced exceptional caviar, it was too late to breed her. (Extracting caviar is a lethal process.) With the genetic markers, however, it is now possible to work backwards—to look at a donor female's genetic profile and ancestry, and then through trial and error deduce which family groups produce superior caviar.

White sturgeon like the one above can reach gargantuan proportions, though today such large catches are extremely uncommon. Photo courtesy: Oregon Historical Society

"There is no doubt that the sturgeon industry would not exist without Sea Grant as a funding mechanism. Sturgeon farming has been a great collaborative work between researchers, Sea Grant, the California Department of Fish and Game, and the industry."

—Peter Struffenegger, general production manager, Stolt Sea Farm California, LLC

Sea Grant Responds to Invasive Seaweed *Caulerpa taxifolia*

Caulerpa Be Gone...

According to the most recent survey of the Agua Hedionda Lagoon in Carlsbad, the *Caulerpa* infestation has shrunk from a peak of about 11,000 square feet to about 4 square feet. This is a dramatic reduction but not the end goal of total eradication.

"It is like a house on fire," said Carlsbad senior planner Eric Muñoz, the city's liaison to the Southern California *Caulerpa* Action Team, a multi-agency group that is leading the eradication effort. "The flames are gone, but the house is still smouldering. Likewise, the eradication is not done."

In terms of Sea Grant's role in the *Caulerpa* eradication effort, Muñoz said: "I see Sea Grant as a credible interface between the world of science and the resource agencies. Sea Grant is a vital part of explaining the problem, communicating the solution and keeping stakeholders updated."

Caulerpa taxifolia is a bright green, feathery seaweed, infamous for destroying huge tracts of habitat on the bottom of the Mediterranean Sea. The seaweed grows quickly, is hearty and attractive—traits that make it both an ideal plant for aquaria and an extremely difficult one to eradicate once established in the wild. The first documented patch of *Caulerpa* in the Mediterranean was identified around 1984. Tests later showed the plants were clones of ones cultured for display at the Stuttgart Aquarium in Germany and shared with aquaria in France and Monaco. That initial patch, about one-square meter in size, spread faster and farther than anyone could have then imagined, covering everything—sand, gravel and boulders—in a feathery green monoculture, comparable to a living carpet of Astroturf.

Today, more than 32,000 acres of the seabed from Tunisia to Croatia are covered in a vast *Caulerpa* monoculture, a rolling meadow of one foreign toxic plant, providing neither habitat nor food for native marine life. Fishing, recreational diving, tourism and marine life have all suffered. Eradication is no longer a discussed possibility. Scientists speak of trying only to control the seaweed's steady march. *Caulerpa*, along with species such as zebra mussels, are held up as case-in-point reasons for gathering international support for preventing the further introduction and spread of nonindigenous species.

In June of 2000, much to the dismay of biologists, *Caulerpa* was found in North America for the first time, in two lagoons in Southern California, at the Agua Hedionda Lagoon in Carlsbad and in Huntington Harbour in Orange County. Recognizing the

An aerial view of the Agua Hedionda Lagoon in Carlsbad, California. *Caulerpa* has infested two sites in North America, both in Southern California. The infestation at the lagoon is of particular concern because the waterway is connected to the open ocean. Photo: City of Carlsbad

potential for the plant to spread uncontrollably, California Sea Grant and other state and federal agencies quickly organized to make sure that what happened in Europe would not repeat itself in the United States. Although *Caulerpa* has not yet been totally eradicated, there is hope that it will be. As of mid-2002, the biomass of the *Caulerpa* infestation in Carlsbad had been reduced by about 90 percent.

In collaboration with other agencies, Sea Grant provided support for three key projects designed to help agencies eradicate existing infestations and prevent new ones. The projects were also tailored to complement a larger, multi-agency *Caulerpa* eradication effort led by the Southern California *Caulerpa* Action Team (SCCAT) and the biological consulting firm, Merkel and Associates. The California Regional Water Quality Control Board, the National Marine Fisheries Service and the California Department of Fish and Game are members of SCCAT.

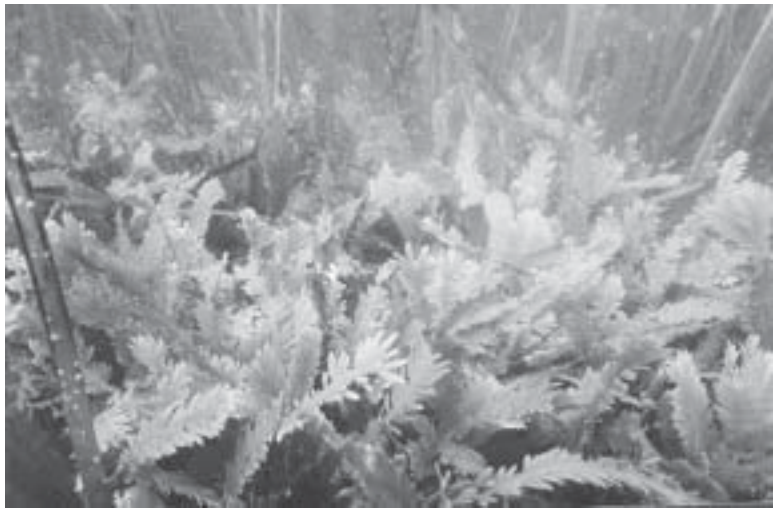
A point of pride for Sea Grant is the rapidity with which we were able to respond to the discovery of *Caulerpa*. Through our Rapid Response program, which provides a mechanism for dealing with urgent, marine-related issues, Sea Grant scientists were able to initiate their projects soon after *Caulerpa* was identified. Such prompt attention is not common within the structure of most marine-science funding programs. As the situation in Europe has painfully shown, hesitancy from Sea Grant, or any other institution, could have been disastrous. Of particular concern is the possibility for the seaweed to spread to the open coast, where containment would become costly and technically very difficult.

"We said early on, we were not going to duplicate the mistakes of the past. The reason we have been so successful is that all the groups involved have worked collaboratively, that includes Sea Grant."

—Bob Hoffman, Southern California environmental coordinator for the Southwest Regional Office of the National Marine Fisheries Service, the lead federal agency in the *Caulerpa* eradication effort.

To evaluate areas vulnerable to future infestations, Sea Grant funded Dr. Susan Williams, director of the Bodega Marine Laboratory of University of California at Davis, to map out the potential geographic range of *Caulerpa* based on available light, salinity and coastal ocean water temperatures. Her research looked at how far and how fast *Caulerpa* could potentially spread, and she identified waterways that share the characteristics most favorable to the introduction, proliferation and spread of *Caulerpa*. Her work suggests that all lagoons in Southern California are at potential risk, as well as colder waters in Oregon and even Washington. Mexico is also at potential risk. Originally a tropical seaweed, *Caulerpa*, Williams reported, has become tolerant to colder coastal climates. San Francisco Bay is at high risk, she added, because it is a destination for "live rock" shipped overseas for the aquarium trade. Live rock is typically a piece of live coral covered with other living marine organisms. *Caulerpa* fragments have been found on live rock imports.

In the second Sea Grant project, biologist Dr. Steven Murray of California State University, Fullerton, and Sea Grant Trainee Susan Frisch documented the commercial availability of *Caulerpa* at retail aquarium stores in Southern California. Of the 50 stores visited for their survey, 52 percent sold specimens of the genus *Caulerpa*. Ten percent sold the invasive strain of *C. taxifolia*. About 95 percent sold live rock. Since their



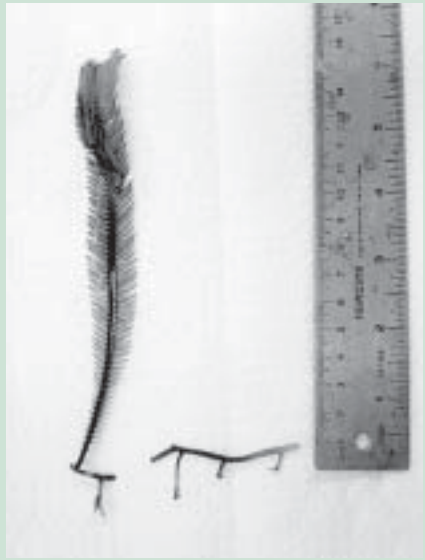
A close-up of *Caulerpa* growing among eel grass shoots in Agua Hedionda Lagoon in Carlsbad, California. Photo: City of Carlsbad

survey, the California legislature has banned the importation, possession and intrastate sale of nine *Caulerpa* species, three of which are known to be invasive and six of which are nearly indistinguishable from the invasive varieties. The interstate sale of *C. taxifolia* is illegal under the Federal Noxious Weed Act of 1999.

The third Sea Grant project targeted public education—perhaps the single most important component of the SCCAT team's eradication strategy, because unlike other invasive species, the general public can introduce and spread *Caulerpa*. It is believed that *Caulerpa* was introduced to Southern California by residents who had emptied their home aquaria into nearby waterways. Boating, recreational diving and fishing can also spread *Caulerpa*, because tiny torn fragments of *Caulerpa* have the capability of growing into entire new plants.

To educate the public about the seriousness of *Caulerpa* and other marine exotics, Sea Grant collaborated with the Birch Aquarium in La Jolla and funded biologist Dr. Enric Sala of Scripps Institution of Oceanography to create a colorful, educational exhibit on *Caulerpa*. The display—a 5- by 10-foot panel—shows people what *Caulerpa* looks like, explains the dangers of releasing home tanks into waterways and explains how even microscopic *Caulerpa* fragments can grow quickly into new adult plants. The public was also alerted to the importance of reporting all *Caulerpa* sightings to appropriate agencies. The exhibit is on display at the Birch Aquarium.

Despite the best efforts of the groups involved, as of mid-2002, *Caulerpa* had not been eradicated at either the Agua Hedionda or Huntington Harbour. As part of its ongoing effort help expunge the seaweed, Sea Grant co-sponsored the first international workshop on *C. taxifolia*, held in San Diego, January 31–February 1, 2002. The meeting was attended by a blue-ribbon panel of scientists and resource managers from six countries, including France, New Zealand, Australia and Croatia, as well as by local agencies, city officials and planners involved in the Southern California cleanup.



A *Caulerpa taxifolia* frond. Possession of these once popular aquarium plants is now illegal in California. Photo: Lars Anderson, Weed Science Program, UC Davis

Among the many positive outcomes of the workshop, resource managers were able to discuss the merits of different eradication schemes and from these interactions, to identify further research needs.

Surf-Zone Drifters: A New Tool for Studying Nearshore Circulation

With California Sea Grant funding, coastal oceanographers have built a satellite-tracked drifter capable of withstanding the pounding force of breaking waves. The surf-zone drifter, the first of its kind, represents an important addition to an ever increasingly sophisticated arsenal of tools for studying the coastal ocean. Unlike current meters, which measure water velocities at fixed points, the new drifter moves with ocean currents, tracing out a trajectory that represents the space-time evolution of a water parcel through the surf zone. These trajectories make it possible to unravel some of the more subtle physics of surf-zone circulation, such as the evolution and development of rip currents.

The new instrument also has many potential applications for coastal communities interested in maintaining beach water quality. A fleet of the drifters, for instance, could be used to help estimate the rate at which water along the coast is exchanged with deeper, cleaner waters outside the surf zone. This exchange rate in turn could be used to help quantify the dispersion and fate of coastal pollution from point sources and urban runoff. The drifters could also conceivably be used to help coastal engineers evaluate the effects of jetties, groins, artificial reefs or seawalls on nearshore circulation, sand loss and coastal erosion.

The drifter, designed by Sea Grant trainee Wilford Schmidt and engineers Brian Woodward and Kimball Millikan, all of Scripps Institution of Oceanography, stands about a meter tall and looks like a long white can with an antenna sticking out the top. Its exterior hull is made of white polyvinyl chloride (PVC) piping. Sealed inside, there is a Global Positioning System receiver, a data logger and a radio transmitter. There are also batteries and an internal lead weight for ballasting.

Each drifter receives its position from earth-orbiting satellites and transmits its position to a shore-based tracking system, making it possible for researchers to monitor the movements of many drifters on a single plot in real-time.

Technicians wade into the surf to deploy new surf-zone drifters. Photo: Georgia Ratcliffe, California Sea Grant

By design, the drifter floats in a vertical, upright position, its black cap skimming just beneath the surface. Only its antenna actually protrudes above the waterline. A thin PVC disk at the base of the drifter is designed to help dampen vertical excursions (e.g., cork-like bobbing) of the drifter in the surf.

Laboratory tests in wave tanks at Scripps have proven the drifter's fidelity to its purpose. The drifter essentially moves with water parcels and only to a much lesser extent is pushed by breaking waves and winds. Wind tunnel tests indicated a 1-centimeter-per-second slippage for every meter-per-second of wind. Subjected to nonbreaking waves, the drifter moved only slightly, as predicted by linear wave theory. In breaking waves, the drifter moved slightly in the horizontal direction but not vertically, relative to the seafloor. This vertical stability prevents the drifter from being washed to shore, like a beach ball or lost surfboard.

One of the immediate applications of the new tool has been to study rip currents, seaward jets that often carry swimmers out beyond the surf zone. In the summer of 2001, Schmidt, Scripps professor Robert Guza,

A technician radios scientists to tell them he has recovered a drifter. Photo: Georgia Ratcliffe, California Sea Grant

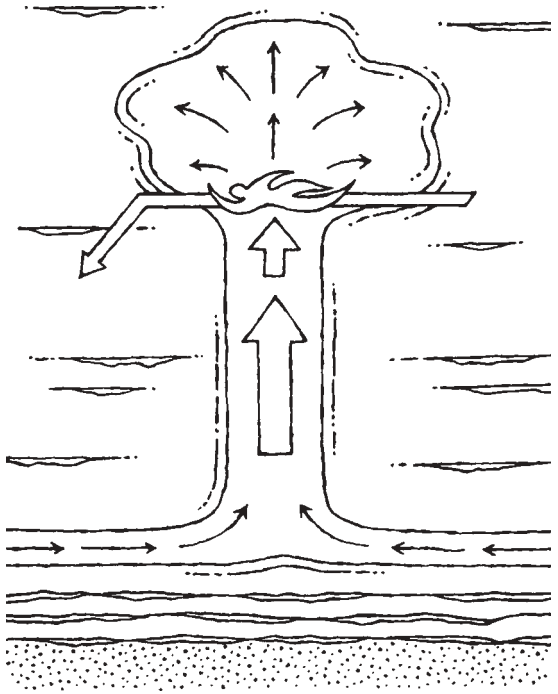
engineers and technicians successfully deployed a fleet of 10 drifters at the base of a rip current located about a quarter-mile south of the Scripps pier.

The drifters' paths revealed a never-before-measured feature of the surf zone, large eddies (circular currents) at either side of a rip. Swirling waters have been reported anecdotally, predicted by ocean theoreticians and suggested in some numerical simulations, but this was the first time researchers had actually measured them.

By overlaying drifter trajectories on maps of bathymetry, the scientists have also been able to discern a connection between the shape of the seabed and the location of rip currents.

The width of the surf zone seems to exert some control over rip currents, as the scientists reported the drifters accelerated as they traveled seaward. They reached a maximum speed at the edge of the surf zone—some two to three times faster than average. Width may also play a role in determining the seaward extent of a rip current.

A second deployment of the drifters was repeated in the summer of 2002 along the same stretch of beach as the year prior. The scientists have not yet analyzed the data, but it will be a key part of Schmidt's doctoral thesis, "Spatial and Temporal Variability of a Rip Current."



By some accounts, rip currents are the cause of 80 percent of all distressed swimmer rescues. Often erroneously called undertows, rip currents do not pull swimmers down, but carry them offshore through the surf zone. If caught in a "rip," the swimmer should not panic, but swim calmly parallel to the shore. Rip currents are narrow and can be escaped easily in this manner. Illustration: North Carolina Sea Grant

Modeling Water Quality and Sediment Transport in Two California Bays

To better understand the processes that disperse pollution, move sediments and trigger toxic algal blooms, California Sea Grant has funded two UCLA professors to develop a computer model of the 3D flow patterns in Santa Monica and Monterey bays.

The model will be used to produce a series of simulations showing what happens when pollutants from sewage discharges, pollution leaks or runoff enter the bays. A second goal is to figure out how waves and bottom currents move sediments along the seabed, a question of immediate relevance for understanding the transit route of beach sand and the complex cycling of contaminants such as DDT in sediments.

Preliminary model runs have already revealed some interesting, previously unknown features in the Santa Monica Bay—strong swirling currents 10- to 50-kilometers wide. These mesoscale eddies, which can nearly fill the bay, appear to play a dominant role in determining the residence time of pollutants in the bay since, when an eddy passes through, it flushes out the bay, removing contaminants. Otherwise, the exchange of water into and out of the bay is meager.

It is not yet possible to predict from ocean measurements or computer models exactly when eddies will form. In model runs, they appear every few weeks or so. The simulations suggest they are the product of instabilities, a form of turbulence, in the California Current and Southern California Countercurrent.

When bacterial counts reach dangerous levels, health officials post warning signs, such as the one pictured above on a beach at Scripps Institution of Oceanography, La Jolla. Photo: Georgia Ratcliffe, California Sea Grant

The California Current, the largest current off the coast, flows equatorward, carrying cold water from Alaska. South of Point Conception in Santa Barbara County, the current shifts offshore in summer, allowing a northward flowing Countercurrent to inject warmer water from the south into the Southern California Bight. The commingling of these two currents is one of the reasons for the rich biology of the Channel Islands. It is also a source of unusually strong gradients in current speeds. It is these intense shears that create instabilities in the flows—and thus eddies—the scientists say.

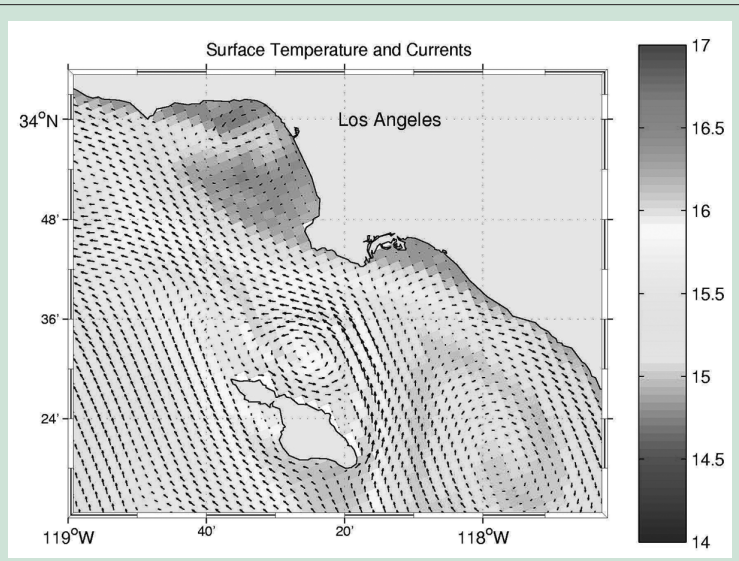
The lead scientist of the study is UCLA civil engineering professor Keith Stolzenbach, whose research focuses on tracking pollutants in Santa Monica Bay. The co-investigator is physical oceanography professor Jim McWilliams, the Slichter Professor of Earth Sciences at UCLA, who in the spring of 2002 was elected a member of the prestigious National Academy of Sciences.

To appreciate what the scientists have done, it helps to understand that most computer models have followed one of two schemes. They have either captured the physics that drive the major currents, the large-scale flows, and ignored or inadequately resolved the physics of the smaller-scale features, mesoscale eddies; or, they have simulated the smaller-scale flows, without taking into

account the influence of the large-scale flows on eddies. Both schemes present inherent limitations, since the major currents and eddies do not exist separately from each other but instead interact and evolve together.

In their current Sea Grant project, Stolzenbach and McWilliams have developed a model that simulates the effects of large-scale flows on local circulation patterns. To do this, they have produced a mathematical algorithm that effectively gives them a zoom lens for viewing details along the coast. To produce this zoom, output from a regional circulation model is used to initialize and set boundary conditions for a series of embedded, or nested, calculations. It is these embedded calculations that capture the effects of the California Current system on local circulation patterns. At present, their model telescopes from a 100-kilometer scale to a 1-kilometer scale in the Southern California Bight.

The regional model, it should be noted, was developed in a previous Sea Grant project in collaboration with researchers at Rutgers University in New Brunswick, New Jersey.



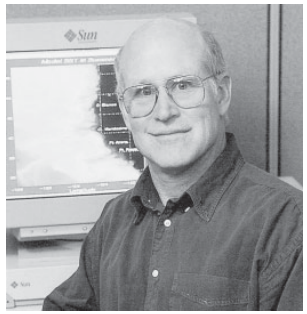
Sea Grant researchers modified a computer simulation of currents along the West Coast to model flows within the Southern California Bight. The above shows a plot of simulated water velocities (the vectors) over a contour plot of sea-surface temperature. Image from: Marchesiello, McWilliams, Oram, and Stolzenbach

To check the accuracy of their model, the scientists are comparing their simulations to real ocean data collected by a variety of sources, including NASA satellite measurements of sea surface temperature, sea level and ocean color. So far, their computations compare favorably to real observations.

The model continues to be fine-tuned as the project is only in its second year. The scientists will incorporate tidal currents and municipal sewage discharge data into the model to help them track the movement of treated sewage along the coast. They also plan to simulate the dispersion of runoff after heavy winter storms. And, because the model incorporates data on nitrogen, chlorophyll, and zooplankton abundance, it will also be possible to look at some of the very simple biogeochemical interactions between upwelling events and phytoplankton blooms.

Another ambitious goal is to work out the physics of sediment transport in the bays. This will require resolving even smaller-scale motions, since sediments are carried by ocean waves and by currents set up by breaking waves. The scientists are currently collecting geologic information to help them estimate the grain size of particles on the sea floor, a key factor in determining how far sediments are carried by waves and currents. They also are similarly modeling flows in the Monterey Bay. Their project is scheduled to be completed in February of 2004.

Keith Stolzenbach is a professor in the Department of Civil and Environmental Engineering at UCLA. Photo: UCLA



James McWilliams is the Louis B. Slichter Professor of Earth Sciences in the Department of Atmospheric Sciences at UCLA. Photo: UCLA

Frontiers in Squid Reproduction: Prospecting for New Antibiotics

Many bacterial diseases—tuberculosis, gonorrhea, staph and strep throat—have developed strains that can no longer be treated with standard antibiotics, leading those in the medical profession on a search for new cures.

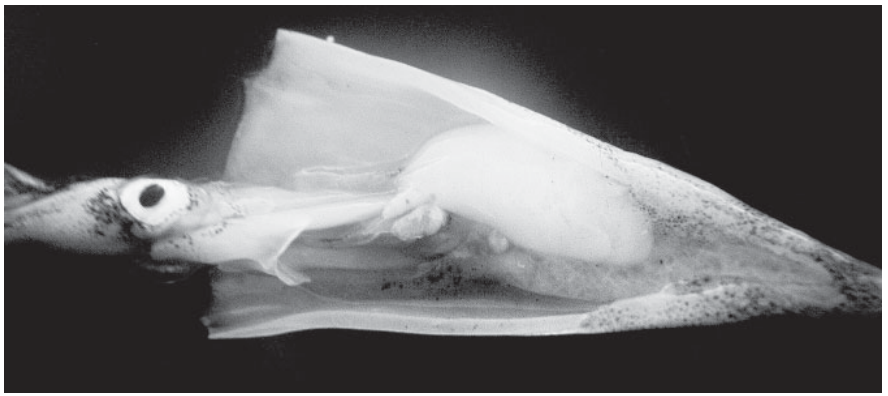
Although most antibiotics have been derived or inspired by the biochemistries of terrestrial life, it is the watery realm of the sea that may provide both the pharmaceutical industry and the public with the next generation of new treatments. Ongoing and past research by Sea Grant biologist Dr. David Epel pointedly illustrates how unraveling the basic biology of marine creatures as common as the California market squid can lead to the discovery of novel biochemical pathways, the Holy Grail of drug development.

For almost a decade, Epel, a biology professor at Stanford University, has been studying what he originally saw as a curiosity of squid reproduction. Female squid lay their eggs on the seafloor without burying or hiding them. For the duration of their 30-day incubation, the eggs sit on the sea bottom, totally exposed to legion microorganisms in seawater. Yet, somehow, they do not rot. They escape both bacterial and viral infection. "How is this so?" he asked.

His first hypothesis was that egg sheaths must contain protective antimicrobial compounds that ward off microbial attack. In this case, he reasoned the eggs would be nearly sterile. His own experiments proved him wrong. The eggs, instead of being free of bacteria, were slathered in a bacteria-rich coating.

That discovery led him to a second hypothesis: the bacteria must play a protective role in guarding against infection. Consistent with this theory, but not unto itself proof of it, Epel showed that female squid inoculate their eggs with a bacterial paste, squeezed out the accessory nidamental gland, a reproductive organ located near the egg-producing nidamental glands.

In a Sea Grant project completed in 2001, he and post-doctoral researcher Dr. Todd Ciche identified 10 previously unknown species of bacteria on egg sheaths and in the accessory nidamental glands of market squid (*Loligo opalescens*). One of the new bacteria, a red carotenoid-producing alpha-proteobacteria, appears to represent a new genus. It is believed that female squid amass these bacteria from seawater.



Female squid cut open to show internal anatomy. Photo: David Epel, Stanford University

Surprisingly, however, none of these 10 bacteria alone were observed to produce antibacterial compounds. That is, when a single species of bacteria was cultured, it did not produce protective compounds. This finding prompted Epel to postulate that the group of bacteria somehow works together, perhaps communicating through chemical signals, to produce antimicrobial compounds.

If this were true, other squid species could be expected to have similar assemblages of symbiotic bacteria on their egg sheaths. This is in fact what Epel observed. In an analysis of bacterial flora on three species of squid—one native to Hawaii, one native to the Mediterranean Sea and the other to the Atlantic—microbial communities on each were dominated by members

"...the watery realm of the sea may provide both the pharmaceutical industry and the public with the next generation of new treatments"

of the alpha subclass of proteobacteria. His conclusion: these proteobacteria must play a key role in protecting eggs. And, he speculates that their common bacterial-defense mechanism has probably remained relatively unchanged during the many millions of years it took for different squid species to evolve and geographically separate.

Though similarities abound, Epel also reported some intriguing differences in the symbiotic bacteria associated with each species. Whereas none of the individually cultured symbiotic bacteria on the market squid produced antibiotic compounds, two of the other three species did: *Sepia officinalis* and *S. pharaonis*. In ongoing Sea Grant research, Epel is collaborating with marine natural chemist Dr. William Fenical of Scripps Institution of Oceanography, also a Sea Grant researcher, to purify and identify antibiotic molecules produced by these bacteria.

So, how then does the market squid protect its eggs? The leading theory is that the complex suite of bacteria must be present to mount a response against infection. In this scenario, the mechanism for defense is called quorum sensing, meaning that key bacteria must be present in sufficient numbers to interact with each other and produce antibiotics.

"While the public may retain its faith in an antibiotic shield against infection, in reality, for every class of antimicrobial drugs developed by the pharmaceutical industry, there's a mechanism of resistance before much time elapses. Therapies once standard for infections have become largely ineffective."

—A 1999 report from an advisory panel convened by the National Institutes of Health, National Institute of Nursing Research

To test this, Epel is collaborating with a researcher at the University of Iowa who has developed a technique for detecting what are known as acyl-homoserine lactones, signal molecules associated with communication between proteobacteria. That is a fancy way of saying Epel is out to learn "who is talking to whom and in what language." The idea, he explained, is that bacteria emit chemical signals that stimulate other bacteria to produce antibiotics or fungicides. If this novel form of antimicrobial defense is indeed what is happening, it could mean that these antibiotic compounds are also working through novel biochemical pathways. This, he said, offers the best chance against supergerms.

Long-time Sea Grant researcher David Epel is the Jane and Marshall Steel, Jr. Professor in Marine Sciences Cell and Developmental Biology at Stanford. Photo: Stanford University

Developing Methods for Producing Marine Compounds in Nonmarine Organisms

In the search for new medicines, no realm of the globe holds more intrigue than that of the sea. Many of the more complex, novel and interesting compounds discovered in the last decade have been extracted from marine organisms—typically soft corals and sponges, marine algae, even bacteria. Yet, despite the sea's promise, as of mid-2002, there was not a single marine-derived drug on the marketplace. Why?

Sea Grant's researchers and others say there are a few intrinsic difficulties. A leading one is that marine animals often contain very low levels of a desired compound, making it nearly impossible to collect enough of a sample for extensive laboratory testing. Animals may also be rare or part of a fragile ecosystem, which would be harmed by intense harvesting. Still other animals, even if they are common, may be extremely difficult to collect.

With Sea Grant funding, Dr. Margo Haygood has developed techniques that may make it possible to produce marine natural products in nonmarine, easy-to-grow organisms. Photo: Scripps Institution of Oceanography

As a result, it is often impractical to pursue developing drugs from wild marine populations. Even in the best cases, drug discovery is a long shot. Given the cost of developing new medicines, researchers and pharmaceutical companies still opt to follow in the footsteps of the past by modifying or synthesizing compounds extracted from terrestrial life.

In this Sea Grant project, marine biology professor Dr. Margo Haygood of Scripps Institution of Oceanography was funded to investigate what could lead to a commercially viable method for producing large quantities of a marine compound in nonmarine, easy-to-grow animals. Because of the obvious commercial applications, her experiments, and her findings, have stirred great excitement within the scientific community as truly making progress in efforts to develop techniques for mass-producing scarce marine natural products. From a more general perspective, Haygood's research goes a long way toward unlocking the ocean's treasure chest of marine compounds for the treatment of human disease.

In her research, the compound of interest is Bryostatin 1, one in a family of macrocyclic lactones called bryostatins. Bryostatins are found in a brown, moss-like colonial marine animal, a bryozoan of the species *Bugula neritina*. Since the 1980s, people have recognized the strong anticancer properties of these compounds and have speculated, but not shown, that bacterial symbionts are involved in their production. The compounds are of added interest because, unlike many cancer treatments, they do not kill cells directly but instead inhibit normal functioning of proteins during cell replication, causing rapidly dividing cells to effectively commit suicide. None of this knowledge, however, has been parlayed into actually treating human disease.

After a series of experiments, Haygood was able to show that bacteria living within *B. neritina* are indeed the source Bryostatin 1. Among the facts that point to this conclusion, *B. neritina* were observed to contain smaller amounts of bryostatin after being treated with antibiotics.

Under the agency's orphan drug program, the Food and Drug Administration is expected to approve Bryostatin 1 for treating esophageal cancer in 2003.

If this happens, Bryostatin 1 will be among the first marine-derived anticancer drugs on the market.

Currently, Bryostatin 1 is extracted from a wild, rare marine organism. Haygood's research, which was funded jointly by Sea Grant and CalBioMarine Technologies, Inc., provides a "supply technology" that it is hoped will make it possible to "grow" Bryostatin at an industrial facility. Such a technology would alleviate pressure on marine ecosystems and lower drug-production costs.

This mosslike clump is actually a colonial marine animal, a bryozoan from which an anticancer compound has been extracted. Photo: Scripps Institution of Oceanography

Haygood and graduate students also identified the genes that code for the production of bryostatins and showed that these genes are expressed in only one bacterium, *Candidatus Endobugula sertula*. This bacterium, experiments have shown, appears to be transmitted from adult bryozoans to their larvae. More commonly, organisms acquire symbiotic bacteria from seawater. The vertical, parent-child, transmission in *B. neritina* ensures that all offspring harbor the bacterium and strongly suggests that the bacteria benefit the bryozoans, perhaps because bryostatins reduce predation of larvae.

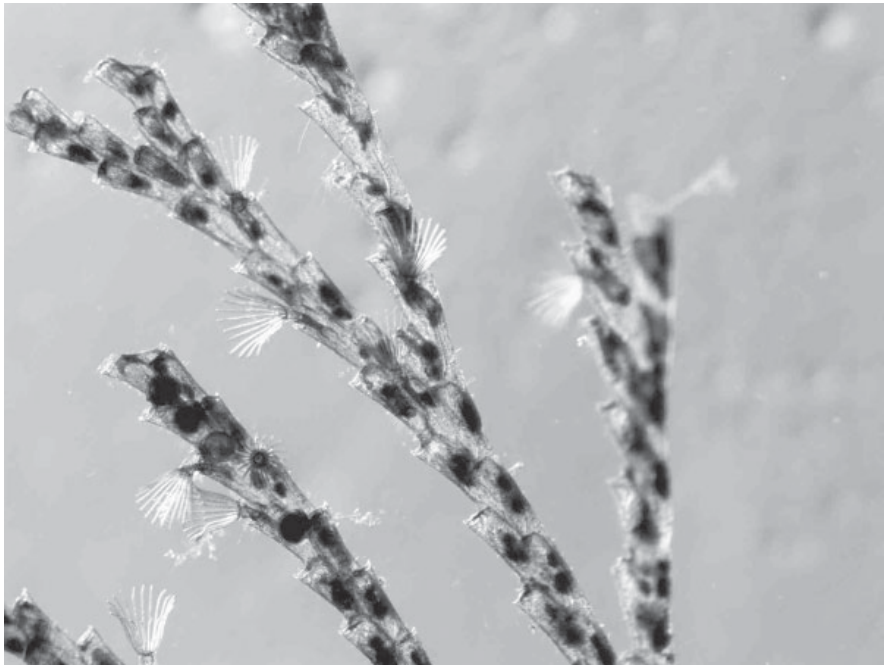
In subsequent experiments, researchers attempted but failed to culture *E. sertula*, a technique that if successful would have provided a means for mass-producing bryostatins. Because culturing proved difficult, Haygood's research took a second tack—that of sequencing the genes believed to be involved in bryostatin production. The gene cluster has proved to be gigantic—about 55,000-base-pairs—as long as some viruses.

In what scientists call pioneering research, Haygood and her team chopped the gene cluster into segments and inserted these shorter units into several different bacteria. The motivation for segmenting the gene cluster: the chopped-up bits are more easily replicated by the host bacteria, making it easier for scientists to sequence the genes. In ongoing

research supported by the National Cancer Institute and the Department of Defense Breast Cancer Research Program, the scientists are trying to insert the entire gene cluster into a single bacterium.

Ultimately, the idea is to find a bacterium whose genetic apparatus will accept the cluster and then synthesize the proteins that produce bryostatins. A bacterium such as streptomyces, already proven in industry as capable of being mass-cultured for antibiotic production, would theoretically be an ideal candidate. If successful, it would be the first time researchers have been able to produce rare marine compounds in genetically altered, nonmarine bacteria. Haygood's Sea Grant research has led to a U.S. patent, and the licensing rights to this patent have since been bought by CalBioMarine Technologies, Inc. in Carlsbad, California. Bryostatin is now in clinical trials for use in humans.

Her team is continuing its efforts to directly culture *Candidatus Endobugula sertula* and is now examining the bioactivity of other promising compounds from close relatives of *B. neritina*.



The marine invertebrate *Bugula nertina*, a brown bryozoan animal with stringy tufts that look like algae, appears unremarkable and similar to a variety of moss-like sea creatures. Photo: Katherine Sharp, Scripps Institution of Oceanography

"Sea Grant is a great program," said Dominick Mendola, CEO and founder of CalBioMarine Technologies in northern San Diego County. "Sea Grant was willing to take an early-stage gamble when no one else was. This is what a funding agency is supposed to do. Industry cannot afford to conduct early-stage research because it is too high risk."

Haygood's industrial collaborator on the marine compound research project, Dominick Mendola of CalBioMarine Technologies,Carlsbad, California. Photo: CalBioMarine Technologies, Inc.

After 28 Years of Service, Seafood Technology Specialist Dr. Robert Price Retires

Dr. Robert Price. Photo: Rhoda McKnight, UC Davis

Most of us take it for granted that our seafood looks appetizing, tastes fresh and is safe. But if you consider that most seafood is imported, and that much of it is caught in the middle of the ocean, the widespread availability of good, safe seafood—whether it is fresh, frozen, live, smoked or canned—is a feat of modern technology.

In California, no one has contributed more to advancing seafood technology than Sea Grant Extension Seafood Technology Specialist Dr. Robert Price. His applied research, training workshops and endless stream of educational publications have earned him nothing less than superstar status within industry and the nation's 30 Sea Grant programs.

Among his accomplishments since joining the Extension Program in 1974, he established the first successful seafood technology program in the state, the Seafood Technology Extension Program at the University of California Cooperative Extension at Davis. He has been instrumental in helping the nation's seafood businesses meet the first set of federal food regulations on handling and processing seafood. And, he has been the creative force behind the Seafood Network Information Center (SeafoodNIC) at http://seafood.ucdavis.edu, a clearinghouse of information on seafood research, marketing, product development and industry news, which today receives more than 6,000 hits a month from 40 countries.

In the broadest sense, Price, who retired in January 2003, has been a public servant and dedicated liaison between academia and industry. In this capacity, which spans 28 years, he has served as an industry consultant, thesis advisor, teacher, author and editor, media contact, workshop coordinator and researcher. With so many hats, he has given, on average, 40 talks a year—to everyone from food processors to technical sales representatives, retailers, chefs, food editors, government researchers and regulators.

Although education and outreach have been focal points for his program, his involvement in applied research has also been consistent—and consistently well received. His efforts to improve at-sea storage and handling methods for albacore tuna, for instance, helped establish the fresh and frozen albacore tuna industries. The albacore tuna now ranks among the state's most important marine fish resources, with the ex-vessel commercial value of albacore landings currently hitting about $10 million a year. Other projects that further illustrate his contribution to helping the seafood industry prosper include:

- developing techniques for gutting fish; looking at whether processing should be done mechanically or by hand, to fillet, sell whole, cut into steaks or freeze fish;
- reducing fish waste and wastewater produced during processing; and,
- designing seafood packaging for airfreight and extended shelf life.

Among his recent research projects, Price worked with squid fishers to develop at-sea handling techniques to control the color of squid flesh. Because Asian importers, the primary market for California squid, have a strong preference for white squid meat, his work has the potential to

What is Seafood Technology?

Seafood technology can be broadly defined as everything that happens to a fish (or shellfish) from the moment it is harvested to the moment it is eaten.

To appreciate what this may entail, consider that the fillet you had for dinner last night might have been caught in the open ocean 2,000 miles from land, brought by boat to a foreign port, processed, packaged and exported via air cargo half way around the globe, before being distributed by truck to local markets for retail sale.

At any point along the way, if improperly handled, your dinner could have spoiled, turned color, been freezer burned, acquired an off-putting texture, or harbored harmful parasites or microbes. The fact that this rarely happens (and, in fact, cooked seafood causes fewer food-related illnesses than beef or poultry) is a feat of modern technologies, not the least of which are refrigeration and air cargo.

The science (and art) of seafood technology is about devising new techniques for maintaining the safety, appeal, taste and marketability of any one of the more than 300 species of fish and shellfish products sold around the world. Sea Grant, through its Extension Program, has been a leader in advancing seafood technologies for 30 years.

Fish processors at work. Photo: University of California, Division of Agriculture and Natural Resources

Photo: University of California, Division of Agriculture and Natural Resources

substantially increase the value of the squid fishery, which in 1999 was ranked as the most valuable exported edible fishery product in the state. To further help fishers, Price also produced a multimedia CD-ROM, "The Colors of California Squid," which among other things explains that discoloration is only cosmetic and does not pose a health threat. The CD has since been distributed to Asian buyers.

In another recent project, Price worked with shrimp fishers to find a way to rid Pacific ridgeback shrimp of "black spot," a project that, if successful, would also substantially increase the value and marketability of this product.

Though this type of practical, problem-solving research has been a continuous theme through his career, in the last seven years, Price has directed much of his attention to helping industry and government meet new FDA seafood processing regulations, known as the "Procedures for the Safe and Sanitary Processing and Importing of Fish

and Fishery Products." These rules, which went into effect between 1995 and 1997, require anyone selling, importing or handling fish or fisheries products to follow a set of procedures known as the Hazard Analysis Critical Control Point program, or HACCP (pronounced has-sip).

To help plant workers and inspectors identify these "critical control points" and implement HACCP procedures, Price developed and taught "train-the-trainer" courses. As of 2001, HACCP training courses led by Dr. Price and others with the National Seafood HACCP Alliance, an intergovernmental partnership with industry and academia, have reached about 5,000 U.S. processing plants, 6,000 importers and international suppliers, and 14,000 employees and regulators. The benefits to both businesses and consumers have been substantial. In one widely quoted survey, 77 percent of seafood businesses polled said the courses were indispensable in meeting FDA regulations. These courses have also been credited with preventing thousands of seafood-related, potentially lethal, illnesses annually.

"Bob has helped the seafood industry time and time and time again, whenever there was a question of seafood technology. He never let us down."

—Robb Ross, executive director of California Fisheries and Seafood Institute

"Bob has been a great help to us over the years in facilitating training for seafood inspectors and industry. He's been a great resource for the seafood inspection program."

—Eric Staiger, chief of the Western Inspection Branch of the U.S. Department of Commerce's Seafood Inspection Program

Price said that leading these workshops, and many others over the years, has been the highlight of his career. "Looking back over the last 30 years," he said, "I think I am most proud of all the workshops we have led. We have led thousands of workshops on all kinds of topics, for everyone from seafood harvesters to consumers. We have led hundreds of consumer workshops in every little town, to tell people how to buy, store, handle and preserve fish. I think we made a tremendous effort training people."

A former U.S. Secretary of Agriculture and Vice President agree. In 1999, the Secretary of Agriculture awarded the National Seafood HACCP Alliance Steering Committee, on which Price sits, its Group Honor Award for Public Service, in recognition of its effort to help the seafood industry meet new FDA regulations. The Alliance was also awarded the "Hammer Award" from Vice President Al Gore in 1997 for its effort to improve government for the best interest of the nation.

Price will be sorely missed by Sea Grant and the California seafood industry.

Dr. Robert Price. Photo: Georgia Ratcliffe, California Sea Grant

extension program...

The Sea Grant Extension Program mission is to increase the understanding, development, and conservation of California's coastal and marine resources. This is accomplished through research and the application of science-based information to solve problems involving natural resources of the coast and ocean. This mission is carried out by a talented team of seven Marine Advisors with a broad range of expertise operating in coastal counties from San Diego to Crescent City, and one marine fisheries specialist based at the University of California, Davis.

University of California researchers place an array of bagged oyster shell in Tomales Bay to enhance settling substrate and recruitment for larval native oysters. Photo: University of California

SEA GRANT ASSISTS OYSTER RESTORATION IN TOMALES BAY

Sea Grant Interim Director of Extension **Paul Olin** is collaborating with scientists at the University of California, Davis and San Francisco State University on a pilot project to restore native oyster populations in Tomales Bay in Marin County, just north of San Francisco. The group has built and deployed 12 pilot reef structures made of bagged oyster shell and will position another 12 in 2003.

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The goal is to have native oysters and other fish and invertebrates recruit to the complex three-dimensional habitat provided by the shell, and eventually create a sustainable living reef ecosystem. Much of the hard-bottom substrate historically found in the bay, and used by oysters to settle, has been covered in sediments resulting from erosion and runoff from the surrounding watershed.

Olin reports that a major purpose of this research is to document the extent to which the oyster reefs enhance fish and invertebrates on the reefs and in surrounding waters. If the reefs prove to be viable means of enhancing native species, more expansive reefs could conceivably be built as part of a larger restoration effort, or as mitigation for development projects, such as the proposed expansion of the San Francisco International Airport.

ASSESSING FISHERY RESOURCES

In the last decade, catches of many fish species along the Central California coast have greatly declined, due both to decreases in fish populations and to new regulations enacted to conserve or rebuild fish stocks.

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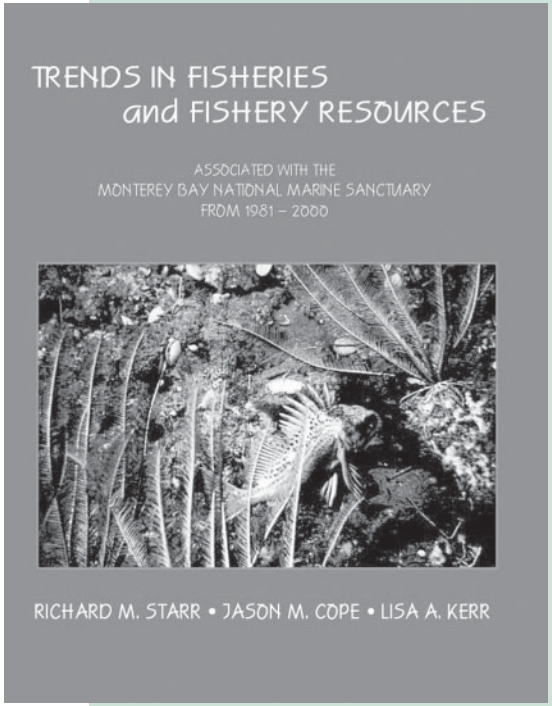
To assist fishery managers, the Monterey Bay National Marine Sanctuary asked Sea Grant Marine Advisor **Rick Starr** and colleagues to compile data on the status of fisheries in the region. Their new book, "Trends in Fisheries and Fishery Resources Associated with the Monterey Bay National Marine Sanctuary from 1981–2000," was published in 2002. It summarizes the technical concepts and information typically used to estimate fishery population sizes, provides brief descriptions of the types of fisheries operating in each habitat type, and summarizes fishery management options.



They found that more than 1,200 commercial vessels annually fish within the Sanctuary, about a 40% decline since the 1980s. Total catches have increased as commercial fishers have targeted abundant pelagic species such as Pacific sardine and squid, but landings of all other species combined have greatly decreased. Catches and effort in recreational fisheries since the late 1980s have slighted declined, but recreational harvests still exceed commercial harvests for many nearshore species.

Photo: Richard M. Starr, California Sea Grant Extension Program

In another fisheries project in 2002, Starr reviewed studies of the effectiveness of four fully protected marine reserves in California: three in the Monterey Bay National Marine Sanctuary (Hopkins Marine Life Refuge, Point Lobos Ecological Reserve, Big Creek Ecological Reserve), and one in the Channel Islands National Marine Sanctuary (the natural area on the north side of East Anacapa Island). The authors compared the reserve effects apparent in the existing reserves with effects predicted by the scientific literature, and a National

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Marine Advisor Susan McBride, winner of a National Sea Grant award to study juvenile rockfish. Photo: California Sea Grant Extension Program

Research Council report on marine reserves.

The review concluded that the small size of existing marine reserves in Central California prevents them from achieving many of the goals and benefits attributed to marine reserves in the scientific literature. However, the older marine reserves in Central California did show some of the primary benefits associated with protection from exploitation, including modest increases in size and abundance of fishes.

In 2002, Starr organized a workshop to identify research needs related to marine sanctuaries in Central California, where recent legislation will directly affect the lives of individual marine users and coastal communities. The objectives of the workshop were to identify the types of information needed to determine how resource management policies affect coastal communities, and to identify current socioeconomic research activities, gaps in knowledge, and priority areas for future research. The recommendations of that workshop are published on the California Sea Grant web site.

Starr also serves on several committees that are responsible for fishery management plans in the Monterey Bay National Marine Sanctuary.

NEW SURVEY CONDUCTED OF ROCKFISH HABITATS

Sea Grant Marine Advisor **Susan McBride** of Humboldt and Mendocino counties has won a competitive grant from the National Sea Grant College Program's Fisheries Extension Enhancement Program to conduct a year-long survey of juvenile rockfish populations in California and Oregon.

McBride's project is designed to help both state and federal agencies develop fishery management plans for rockfish species generically marketed as red snapper or rock cod. Fishermen will play a central role in the project's fieldwork. They will work with McBride to establish sample sites, and during charters will set and recover traps, measuring and identifying all fish. The objective of this research is to identify essential habitats used during different life history stages.

The goal is to understand what kinds of habitats—such as rock reef, kelp forest, eel grass or sand and boulder—newly settled fish utilize and for how long. Sampling will be conducted monthly at nine sites, and all sites will be sampled within a two-week window to capture "pulses" of rockfish settlement. The sites that will be monitored in California are Morro Bay, Monterey Bay, Bodega Bay, Humboldt Bay, Fort Bragg and Crescent City. The Oregon sites are Port Orford, Coos Bay and Newport.

The project is a collaborative effort led by California Sea Grant Extension, with scientists from Oregon Sea Grant, the National Marine Fisheries Service (NMFS), the California Department of Fish and Game (CDFG), the South Slough Estuarine Research Reserve, the Oregon Department of Fish and Wildlife, and the Pacific Marine Conservation Council. Both CDFG and NMFS are in the process of developing fishery management plans for rockfish species. McBride's project complements an ongoing CDFG survey of adult rockfish populations.

There are more than 60 species of rockfish off the U.S. West Coast. Within the last decade, many of these stocks have plummeted to catastrophically low levels, to the point that huge swaths of the shelf have been closed to groundfish fishing. McBride said that some of these deep-water species may use shallow water habitats during their early life stages, migrating to deeper waters as they get older. The project may be able to confirm whether this is true and for what species.

McBride is also hoping to work with fishermen to establish "index sites," which could be monitored as proxy estimates of young rockfish abundance in the surrounding areas.

Photo: Michael Nevins, U.S. Army Corps of Engineers

BALLAST WATER PROJECT ENTERS FOURTH YEAR

Ballast water discharged from ships has been identified as a primary means by which non-native plants and animals are transported around the globe and introduced into foreign coastal waters. Most of these species die, but some of them not only survive but thrive in their new habitats, often displacing native species and altering native habitats. This problem has caused millions of dollars in economic and environmental damage

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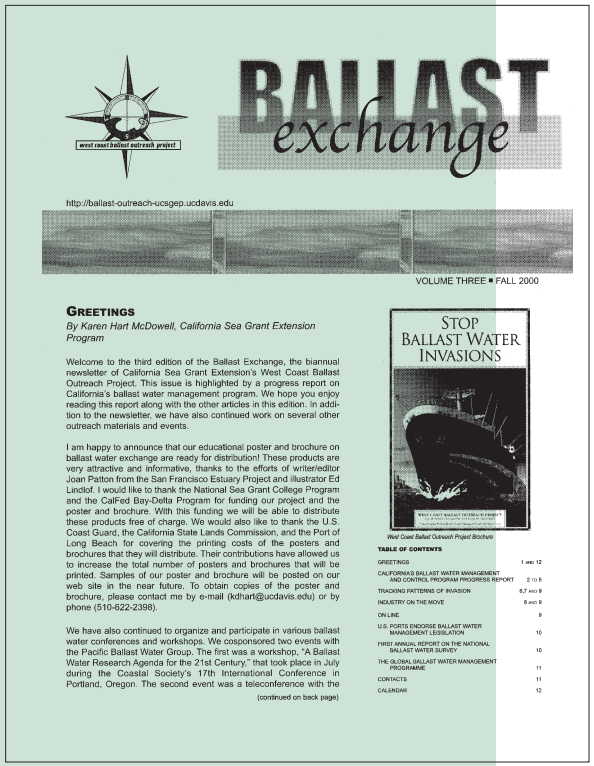

BALLAST exchange

west coast ballast outreach project

http://ballast-outreach-ucsgep.ucdavis.edu

VOLUME THREE ▪ FALL 2000

GREETINGS

By Karen Hart McDowell, California Sea Grant Extension Program

Welcome to the third edition of the Ballast Exchange, the biannual newsletter of California Sea Grant Extension's West Coast Ballast Outreach Project. This issue is highlighted by a progress report on California's ballast water management program. We hope you enjoy reading this report along with the other articles in this edition. In addition to the newsletter, we have also continued work on several other outreach materials and events.

I am happy to announce that our educational poster and brochure on ballast water exchange are ready for distribution! These products are very attractive and informative, thanks to the efforts of writer/editor Joan Patton from the San Francisco Estuary Project and illustrator Ed Lindlof. I would like to thank the National Sea Grant College Program and the CalFed Bay-Delta Program for funding our project and the poster and brochure. With this funding we will be able to distribute these products free of charge. We would also like to thank the U.S. Coast Guard, the California State Lands Commission, and the Port of Long Beach for covering the printing costs of the posters and brochures that they will distribute. Their contributions have allowed us to increase the total number of posters and brochures that will be printed. Samples of our poster and brochure will be posted on our web site in the near future. To obtain copies of the poster and brochure, please contact me by e-mail (kdhart@ucdavis.edu) or by phone (510-622-2398).

We have also continued to organize and participate in various ballast water conferences and workshops. We cosponsored two events with the Pacific Ballast Water Group. The first was a workshop, "A Ballast Water Research Agenda for the 21st Century," that took place in July during the Coastal Society's 17th International Conference in Portland, Oregon. The second event was a teleconference with the

(continued on back page)

STOP BALLAST WATER INVASIONS

West Coast Ballast Outreach Project Brochure

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worldwide, and it is only expected to worsen as global trade and shipping increase.

Sea Grant Marine Advisor **Jodi Cassell** has been working on the ballast water problem in California since 1999, when she received federal funding to launch the West Coast Ballast Outreach Project. With the San Francisco Bay–Delta region having the dubious distinction of being the "most invaded estuary in the U.S.," Cassell's project has paid big dividends in helping the shipping industry and resource managers keep current on changing regulations and new technologies to manage ship ballast water to prevent the introduction of aquatic nuisance species into coastal waters.

The project is co-sponsored by the CALFED Bay–Delta Program and has received a second round of funding from the National Sea Grant College Program to continue it through its fourth year. It's primary goal is providing timely information to the shipping industry, regulators and researchers via a newsletter, workshops and website. The poster and brochure produced during the project's first year have been so popular that they are being requested from around the globe. More than 12,000 copies of the poster and 17,000 copies of the brochure have been distributed. The biannual newsletter, *Ballast Exchange*, includes articles from industry, regulators and environmental groups. Issues can be downloaded from the project's website at http://ballast-outreach-ucsgep.ucdavis.edu.

SMITH RIVER SALMON ON THE RISE

Salmon constitute important species for the economy of California and serve as indicator species for ecosystem function of the state's watersheds, environment and water resources. Since 1980, Sea Grant Marine Advisor **Jim Waldvogel** has been conducting a fall chinook salmon spawning escapement study on Mill Creek, a major tributary of the Smith River in Northern California, to determine the relative abundance of

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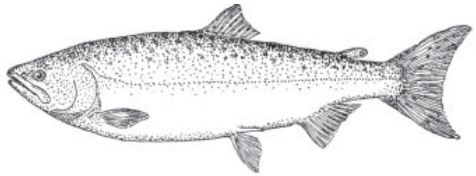
fall chinook over a 23-year period as habitat changes occurred.

The Smith River in Del Norte County is the most pristine undammed river in California. It is host to excellent salmon and steelhead populations and serves as a benchmark for salmonid habitat and effective management. This research project is providing a long-term database to guide fishery managers on the Smith River system. The chinook spawning population is monitored weekly from November through February, and an annual age composition is determined from scale analysis. Fluctuating chinook populations are reflecting drought effects, ocean habitat and feeding conditions (El Niños and upwelling), and some habitat changes.

The salmonid database from this long-term study was used in 1993 to deter a proposed state highway project that sought to relocate Highway 101 into portions of the Mill Creek drainage. Denial of this proposal was based on the high salmonid fishery values of Mill Creek and saved California taxpayers over $30 million.

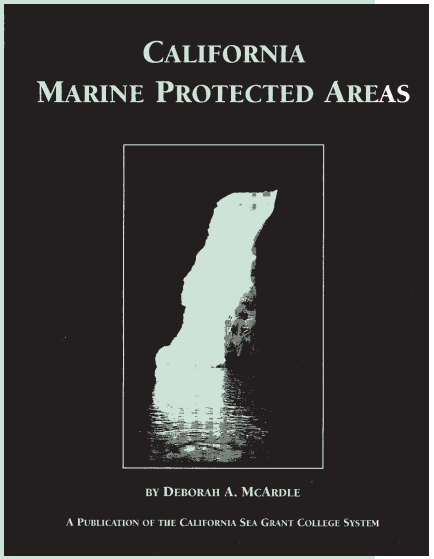
Between 2000 and 2002, there were more spawning chinook than in any of the previous 23 years. Waldvogel attributes this to a shift in the phase of the Pacific Decadal Oscillation. This new phase, which could last some 30 years, is associated with cooler than normal ocean water temperatures in California, increased upwelling and enhanced coastal productivity. Though favorable to California salmon, the shift could reduce Alaska salmon numbers.

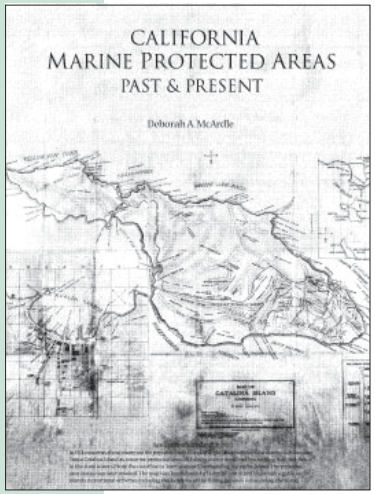


In 2001, the 22-year fishery database allowed the landowner, Stimson Lumber Company, to negotiate a $60-million sale for the 25,000 acres of the Mill Creek watershed to Save-the-Redwoods League. Almost $20 million of the land value was attributed to the Sea Grant long-term salmonid study that documented coho and chinook abundance estimates. The Save-the-Redwoods League has since turned ownership of the land over to the California State Parks, preserving this resource for future Californians.

Waldvogel's salmon count, the longest on record in the area, will be an important piece of fish resource information as the state develops a

Marine Advisor Jim Waldvogel has been counting chinook salmon and their carcasses in the Smith River in Del Norte County for more than two decades. Photo: California Sea Grant Extension Program





management plan for the new park. The results of the 23-year study will be published and will include data through 2002.

CREATING MARINE PROTECTED AREAS

From 1999 to 2001, Sea Grant Marine Advisor **Deborah McArdle** participated in a stakeholder forum to design a marine protected area network for the Channel Islands mandated by California legislation.

Marine protected areas (MPAs) are one of the newest strategies used to manage and conserve marine resources. They are sections of the ocean set aside to protect or restore habitats and ecosystems, conserve biological diversity, provide a sanctuary for sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the environment, and help rebuild depleted fisheries.

The Channel Islands effort was coordinated by both the Channel Islands National Marine Sanctuary and the California Department of Fish and Game (CDFG) at the request of the State Fish and Game Commission. McArdle served on the Marine Reserve Working Group together with commercial and recreational fishermen, kelp harvesters, small coastal business representatives, divers, conservation groups and members of management agencies. Their goal was to design an MPA network that would balance ecological needs with socioeconomic concerns.

While reaching consensus proved to be elusive, the group did construct a series of alternative plans that the California Fish and Game Commission used to designate 12 MPAs in the Channel Islands. These form a network that covers 142 square nautical miles within the Channel Islands National Marine Sanctuary. Ten of the 12 areas are "no-take marine reserves," where no fishing or harvesting of kelp is allowed. Two of the 12 areas are "conservation areas" and allow for limited recreational fishing and commercial lobster trapping.

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To educate the public about the new protected areas, McArdle produced a four-page publication that describes the 12 new MPAs at the Channel Islands, titled "California Marine Protected Areas, An Update." The publication, produced in cooperation with the CDFG and the Channel Islands National Marine Sanctuary, was mailed to all members of the MLPA working groups by the CDFG and is available from Sea Grant.

McArdle has also recently published a booklet, "California Marine Protected Areas: Past and Present," with a grant from the David and Lucile Packard Foundation. It presents examples of the historical, anthropological, ecological and research-based information relating to marine reserves along the California coast. The publication was mailed to all Southern California commercial and recreational fishermen by CDFG and is also available from Sea Grant.

SCIENTISTS EXAMINE STATUS OF CALIFORNIA'S MARINE RESOURCES

Much of California Sea Grant's work in marine fisheries in recent years has been in helping the state implement its Marine Life Management Act, which became law on January 1, 1999.

The California Department of Fish and Game (CDFG) contracted with Sea Grant Extension Fisheries Specialist **Christopher Dewees** to collaboratively publish a major report, "California's Living Marine Resources: A Status Report," 2001. It is a 592-page resource for fisheries managers, interested citizens, legislators, students, industry, and marine biologists.

The report examines the population status and biological information on the current state of more than 150 commercial and recreational species and discusses the natural history of many of the plants and animals in California's marine environment. It includes the writings and contributions of more than 125 leading marine scientists affiliated with CDFG, the University of California, the California State University, the National Marine Fisheries Service, the National Oceanic and Atmospheric Administration, and numerous private organizations.

The book also provides valuable insights into the relationship between the state of California's marine resources

Squid fisherman. Photo: Edward J. Pastula, NMFS

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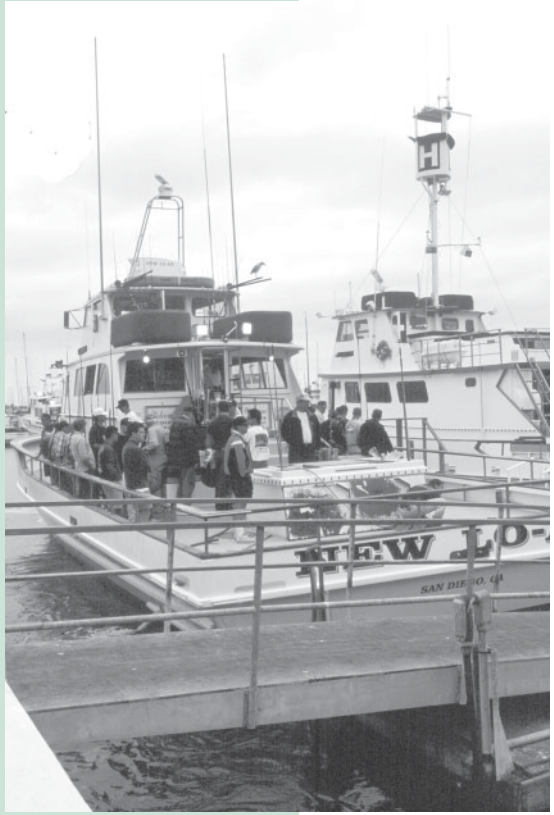

Recreational fishing day boats. Photo: William B. Folsom, NMFS

and their contributions to the state's economic prosperity. Among its findings:

- The commercial fishing industry generates approximately $550 million in total income and provides nearly 17,000 jobs.
- Recreational fisheries generate $5 billion in personal income and account for more than 150,000 jobs.
- California's market squid fishery has emerged as one of the most important in the state. In the 1990s, it ranked as the largest and most valuable commercial fishery resource, generating up to $40 million annually.
- California's highly variable ocean conditions profoundly influence the abundance of many marine organisms and add to the complexity of managing living marine resources.

This comprehensive guide is available from California Sea Grant.

HELPING BOATERS SWITCH TO NONTOXIC PAINTS

Beneath the surface of San Diego Bay there is trouble brewing. Thousands of recreational boat hulls are slowing leaching toxic copper ions into the water.

For decades, boaters have relied on paints high in copper to protect boat hulls from fouling by algae, barnacles and worms. As San Diego has grown, so have copper levels in the Bay, to the point where the copper poses environmental and economic threats to animals and people. Local governments might soon be faced with the high costs of removing contaminated sediments from the Bay in order to meet water-quality regulations. There is no law banning copper paints right now, but regulatory controls may not be far off.

To help San Diego stay ahead of potentially stricter water-quality regulations, Sea Grant Marine Advisor **Leigh Taylor Johnson** is spearheading a series of projects to educate the boating community about environmentally friendly alternatives to copper-based paints.

"We are trying to prepare people for the laws that likely will be enacted in the next 5 to 10 years," she said.

After thoroughly researching the issues and available products, Johnson has published a free brochure that

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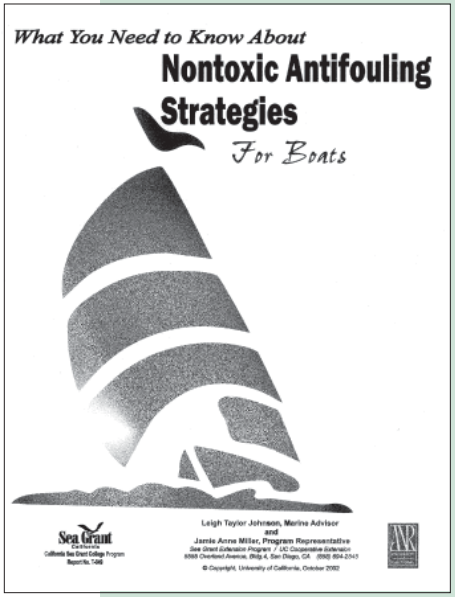
Nontoxic bottom paint being applied to boat hull. Photo: Jamie Miller, California Sea Grant Extension Program

discusses the issues and lists alternative paints and manufacturers. She organized a demonstration project and field day to show boat owners how to make the switch to nontoxic paints and plans to hold more. She is also studying how to create an economic incentive program to encourage boaters to try copper-free paints.

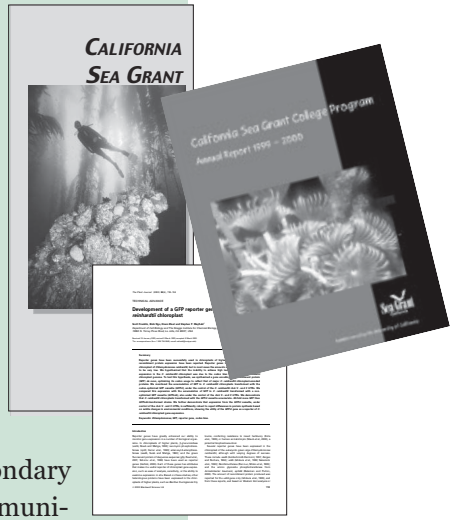
Johnson and her assistant, Jamie Miller, have been speaking with people at local marinas, yacht clubs and boat repair yards to get the word out about the new paints.

To learn more about this topic, visit the web site at http://seagrant.ucdavis.edu.



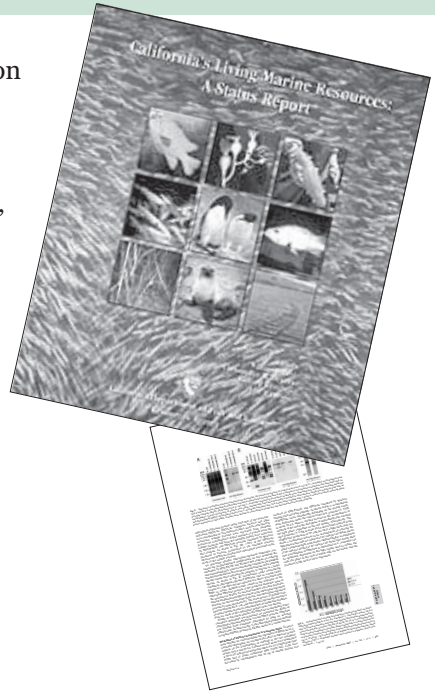
communicating science to the public…

From March 1, 2000 to February 28, 2002, California Sea Grant Communications produced 33 publications that describe on-going research projects and present the results of Sea Grant research and outreach activities. These publications were widely distributed to both scientific and lay audiences at state and national levels. Another 97 publications (including journal reprints, dissertation abstracts, technical reports, and conference proceedings) resulting from Sea Grant-sponsored research and activities were made available to user communities and advertised via newsletters, publication lists and the web site.

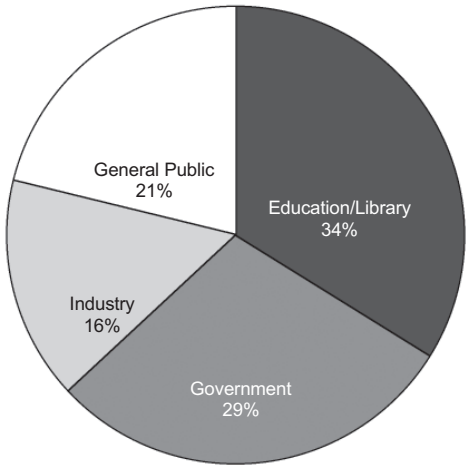


Two outreach projects each produced a video; a third project produced an electronic publication for the Internet; and a fourth produced a workbook for secondary school science teachers. Communications produced 31 additional publications, including newsletters, news releases, award and publication announcements, and brochures that were distributed to target audiences throughout the state and nationally.

The California Sea Grant Extension Program partnered with other agencies to produce a 592-page comprehensive guide, "California's Living Marine Resources: A Status Report." The West Coast Ballast Outreach Project published and distributed to the shipping industry 13,000 copies of an educational poster, 17,000 copies of a brochure and several newsletters, which have literally been distributed around the world. Requests for the poster have come from as far away as Australia, India and Singapore.



Much of California Sea Grant's funded research is disseminated to the scientific community through publication in peer-reviewed, scientific journals. The Communications staff supplements this by advertising journal reprints to all its audiences and mailing single copies free of charge upon request. In order to decrease print and mailing costs and gain even broader dissemination, increasingly Sea Grant is making its publications available on its web site and notifying constituents of their availability.



Publication requests by audience.

education...

In order to promote the future wise use of our coastal resources, California Sea Grant invests in the next generation by providing education, training and informal learning opportunities for students from elementary through graduate school.

GRADUATE TRAINEESHIPS

Research projects funded by California Sea Grant generally include a stipend for at least one graduate student trainee who assists the project leader. The research done by the students is often the basis for their thesis. Hundreds of graduate students have been supported by the California Sea Grant trainee program since its inception in 1968.

FELLOWSHIPS

Fellowships in government provide first-hand training in solving today's ocean and coastal resource problems. California Sea Grant's fellowship programs offer unique opportunities for graduate students interested in marine resource policy.

Photo: William Fenical, Scripps Institution of Oceanography

Sea Grant fellows participate in policy development and implementation and acquire the sociopolitical skills needed by today's resource managers. Fellows benefit the legislative committees and government agencies they serve by supplying scientific knowledge of ocean and coastal resources.

Knauss Fellowship

California Sea Grant's Knauss Fellows have been placed with a variety of host offices, including the Ocean Studies Board of the National Research Council, the Office of Fisheries Affairs of the U.S. Department of State, the Division of Ocean Sciences of the National Science Foundation, the U.S. Fish and Wildlife Service, the House Committee on Resources, and NOAA Office of Global Programs.

In 2000, Nelia Forest from UC Berkeley and Lisa Wooninck from UC Santa Barbara were awarded Knauss Fellowships. Forest worked at the Wetlands Division of the Environmental Protection Agency. Wooninck served at the Office of Congressman Sam Farr. In 2001, California Sea Grant's nominees, Alix Cotumaccio of the Monterey Institute of International Studies and Kimberly Puglise of Moss Landing Marine Laboratories were awarded fellowships. They worked at the Coastal Ocean Program Office and the Office of Congressman Bart Stupak (D-MI), respectively.

State Fellowship

California Sea Grant sponsors a State Fellowship Program, modeled after the Knauss Fellowship, which places graduate students interested in statewide marine policy issues with host offices in the California legislature or state resource management agencies.

State Fellows have worked with the state Joint Committee on Fisheries and Aquaculture, the Subcommittee for River Protection and Restoration, the Pacific Fisheries Legislative Task Force, the Monterey Bay National Marine Sanctuary, the California Regional Water Quality Control Board, and the California Coastal Commission.

In 2000, David Hamm, from Scripps Institution of Oceanography, and Megan Johnson of San Diego State University were the California Sea Grant State Fellows. Hamm spent his nine-month fellowship at the Joint Committee on Fisheries and Aquaculture, and Johnson at the Coastal Commission in Sacramento.

The 2001 Fellows were Alina Baspayeva and Rebecca Lameka, both from the Monterey Institute of International Studies. Baspayeva served at the California Research Bureau where she worked closely with Roger Dunstan, Assistant Director, on petroleum platform decommissioning and other related issues. Lameka's term was with the California Ocean Resources Management Program.

Industry Fellowship

In 1995, to strengthen the ties between academia and industry, Sea Grant developed the Industry Fellows Program. In cooperation with specific companies, this fellowship provides support for highly-qualified graduate students who are pursuing research on topics of interest to a particular industry or company. In a true partnership, the student, faculty advisor, California Sea Grant and the industry representative work together on a project from beginning to end.

In 2001, the National Sea Grant College Program awarded industry fellowships to two graduate students in California. Jennifer Carroll of UC Santa Cruz collaborated with Galileo Laboratories, Inc., and Chris Stevenson of UC Santa Barbara with SmithKlineBeecham (now GlaxoSmithKline).

National Marine Fisheries Service–Sea Grant Joint Graduate Fellowship in Population Dynamics and Marine Resource Economics

The National Sea Grant Office and the National Marine Fisheries Service (NMFS) established this new fellowship program in 1999. Its intent is to award fellowships to approximately four new students each year who are interested in careers related to:

- population dynamics of living marine resources and development and implementation of quantitative methods for assessing their status, and
- the economics of the conservation and management of living marine resources.

In 2001, two fellows from California continued their fellowship terms in Marine Resource Economics. Sylvia Brandt of UC Berkeley worked with fisheries scientists at NMFS Northeast Fisheries Science Center. Ronald Felthoven of UC Davis worked at the Southwest and Alaska Fisheries Science Centers.

Brian Fulkerson, the 2000 Isaacs Scholar. Photo: Fred Greaves

JOHN D. ISAACS SCHOLARSHIP

The John D. Isaacs Memorial Sea Grant Scholarship was established in 1981 to recognize excellence in research by high school students, to encourage interest in marine science at the high school level, and to encourage pursuit of scholastic excellence in higher education.

Each year a California high school junior or senior, who presents an outstanding marine science project at the California State Science Fair, receives a scholarship to study at a college or university in California.

The winner in 2000 was Brian Fulkerson of Mount Miguel High School, Spring Valley, California. Fulkerson designed a remotely operated marine vehicle for his project. He is now in his junior year at UC San Diego. The 2001 winner was Hannah Gray who was a senior at Morro Bay High School. Gray examined the ability of oysters to filter pathogenic bacteria from contaminated seawater. Gray attends UC Santa Cruz, and is in her sophomore year there.

The scholarship honors the memory of John D. Isaacs, former professor of oceanography at Scripps Institution of Oceanography, and director of the University of California's Institute of Marine Resources.

K-12

California Sea Grant sponsors modest pre-college education efforts aimed at enhancing K-12 marine science education within the state, and several Sea Grant Marine Extension Advisors play active roles within their local school districts. Sea Grant also collaborates with the UCLA Ocean

Discovery Center (ODC) and the Boys' and Girls' Clubs of Santa Monica to provide experiential learning programs about the marine environment for urban youth. The program increases the outreach capabilities of the ODC and provides the local community with greater access to the University's programs and research.

In addition, California Sea Grant has provided expertise and funding for the development of a marine science camp aimed at elementary and high school students. S.E.A. Lab Monterey Bay is an ocean science camp modeled after NASA's Space Camp. Its goal is to introduce students to the work environment and career opportunities of coastal and marine scientists and policy makers.

Since 2000, California Sea Grant has provided support for the Otter and Surf Bowls—the Northern and Southern California Regional Ocean Science Bowl competitions. The funding provided by Sea Grant helped to implement six-month programs for interested schools to participate in a timed academic competition that focuses on ocean-related topics, organized by the Consortium for Oceanographic Research and Education (CORE).

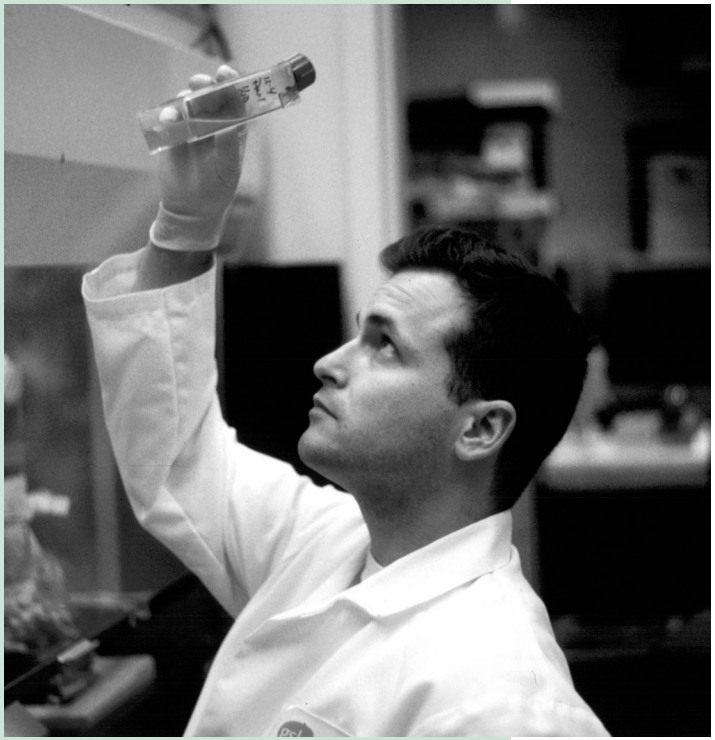
Children participating in an educational marine summer camp at the UCLA Ocean Discovery Center. Photo: UCLA Ocean Discovery Center

California Sea Grant is represented annually at the Educational High Technology Symposium or "Tech Fair" for high school students organized by California Congressman Randy "Duke" Cunningham since 1996. The fair enhances students' appreciation of science and technology and provides insights about career opportunities.

More information about California Sea Grant's education programs appears on the web site at http://www-csgc.ucsd.edu (follow the "Education" link from the home page).

industry fellow...

NOAA's National Sea Grant College Program began the Sea Grant Industry Fellows Program in 1995. Through a national competition, the program provides support for graduate students pursuing research and development projects on topics of interest to a particular industry or company and requires matching funds from the private industrial sponsors.



Sea Grant Industry Fellow Christopher Stevenson worked for GlaxoSmithKline in Philadelphia, developing a new anti-inflammatory drug isolated from blue-green algae. Photo: UC Santa Barbara

California Sea Grant Industry Fellow Christopher Stevenson worked at a laboratory at GlaxoSmithKline in Philadelphia, studying the biomedical properties of scytonemin, a pigment molecule found in blue-green algae, one of the most primitive photosynthetic organisms on Earth. During his tenure, Stevenson consulted with his thesis advisor, Robert Jacobs, a pharmacologist and Sea Grant researcher at the University of California, Santa Barbara, who was the first to discover the pigment's bioactivity. Stevenson also worked closely with company researchers.

"We got together with the common goal of using this marine natural product as an inhibitor of enzymes important in cell proliferation," said Lisa Marshall, a project director in the oncology department at GlaxoSmithKline. "The idea was: if we could inhibit cell proliferation, scytonemin could potentially be an interesting new medicine."

Through his experiments, Stevenson was the first to show that scytonemin inhibits aberrant cell division. He was later able to demonstrate that scytonemin also reduces skin irritations. Stevenson's effort lays the groundwork for an exciting new class of medicines for treating skin inflammation, or potentially any disease that involves aberrant cell division.

Stevenson was awarded a Young Investigator Award at the International Association of Inflammation Society's conference in Edinburgh, Scotland, in September 2001, and second prize at the Inflammation Research Association's national conference in October 2002. Stevenson completed his doctoral degree in pharmacology from the University of California, Santa Barbara in 2002 and is a postdoc at Novartis in England.

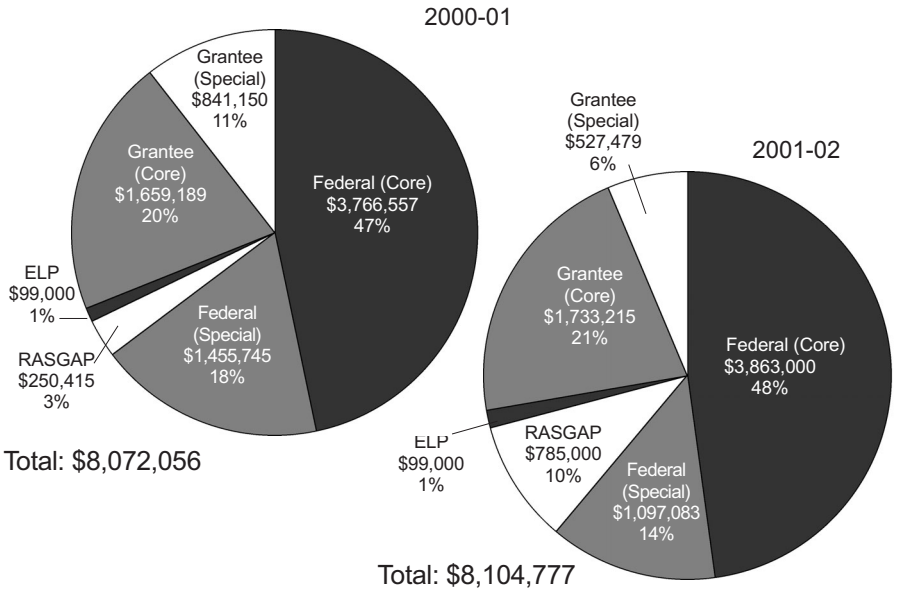
"I was in an industry setting where there were enormous resources. People were always available for questions and happy to help overcome any problems I encountered along the way. I now have a better understanding of what is expected of researchers at industrial scientific institutions."
—Christopher Stevenson

funding and allocations…

California Sea Grant receives the majority of its funding from the National Sea Grant College Program, part of the National Oceanic and Atmospheric Administration (NOAA) in the U.S. Department of Commerce. Core funding applies to projects selected by California Sea Grant for funding through an annual, competitive peer review process. Resources Agency Sea Grant Advisory Panel (RASGAP) funding is from the state of California's Resources Agency, which oversees state agencies that manage natural resources, such as the Department of Fish and Game. Funding from the state of California's Environmental License Plate (ELP) income is allocated in support of the Sea Grant Extension Program.

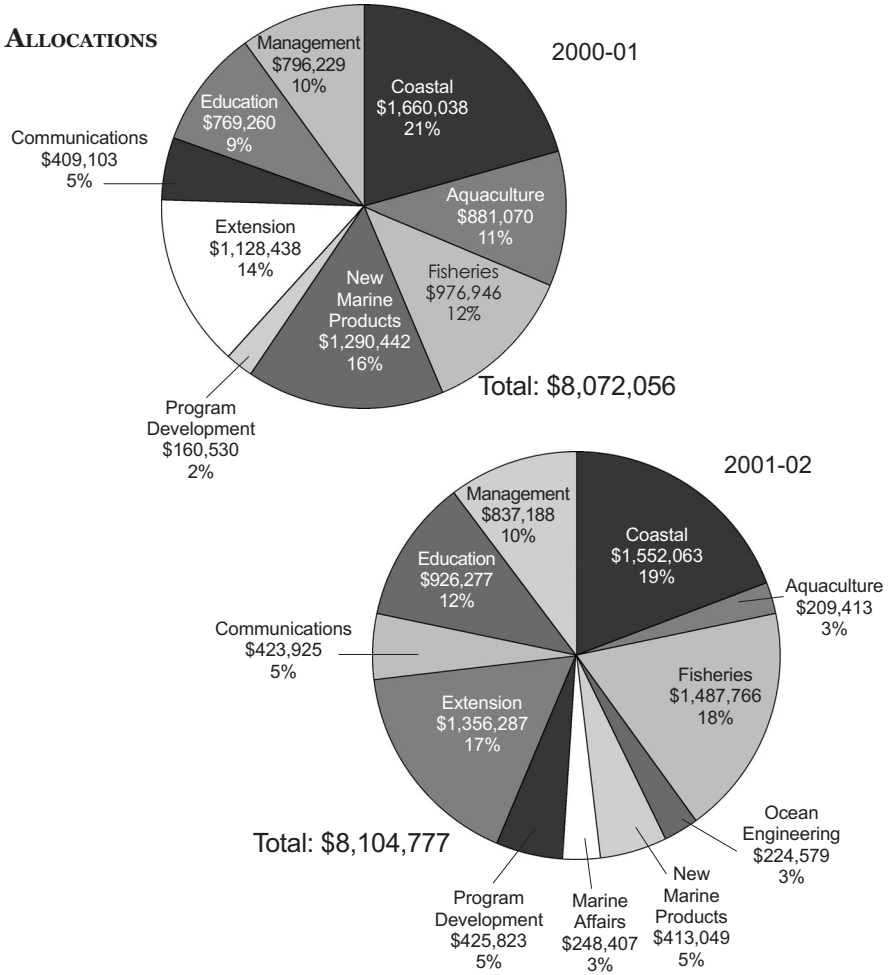
The special initiative category refers to separate competitive grant awards that are run by the National Sea Grant office. The Grantee share refers to matching funds, generally in the form of a researcher's time, which is contributed by the home institution to the project. The following graphs show the relative proportions of funding from each source.

Funding Sources



The graphs below show the relative percentage of combined Core and Special Initiative funds allocated to different activities and subject areas of the program. These amounts change from year to year as a result of the competitive peer review process that is used in the evaluation of all proposals, and in concert with the priorities defined by California Sea Grant, the National Sea Grant College Program, and the RASGAP panel.

Allocations



honors & awards...

• **Lisa Levin**, a professor of biology in the Integrative Oceanography Division at Scripps Institution of Oceanography (SIO), received the University of California, San Diego Chancellor's Associates Award for Excellence in Research.

• **Miriam Polne-Fuller**, Research Biologist, Marine Science Institute, and Director of the Research Mentorship Program, Department of Summer Sessions, UC Santa Barbara, received the Alumni Association Excellence in Teaching Award.

• **Martin Smith**, a trainee with James Wilen, at the University of California, Davis, was winner of the American Agricultural Economics Association essay contest with his submission, "The Marine Environment: Fencing the Last Frontier." Smith was also winner of the Best Student Paper award for "Two Econometric Models of Fishermen Behavior."

• **Paul Dayton**, the late **Mia J. Tegner**, **Peter B. Edwards**, and **Kristin L. Riser**, all of SIO, were recipients of the prestigious William S. Cooper Ecology Award for their winning paper, "Temporal and Spatial Scales of Kelp Demography."

• **Wolfgang Berger**, director of the California Space Institute, SIO, was awarded the prestigious Francis P. Shepard Medal of the Society of Sedimentary Geologists awarded for "excellence in marine geology." It is given in honor of Francis Shepard who taught at SIO for 40 years.

Dr. Wolfgang Berger. Photo: Memorie Yasuda, UC San Diego

• Best student paper award from the American Institute of Fishery Research Biologists went to **Matthew Craig** of SIO, a trainee with Philip Hastings, for his submission, "The Nearshore Fish Assemblage of the San Diego–La Jolla Ecological Reserve."

• A Young Investigator Award went to Industry Fellow **Christopher Stevenson** at the International Association of Inflammation Society's September 2001 conference in Edinburgh, Scotland. Stevenson received his Ph.D. in pharmacology from UC Santa Barbara in 2002, and went on to conduct postdoctoral research at Novartis in England.

Sea Grant Industry Fellow, Christopher Stevenson. Photo: UC Santa Barbara

• **Pamela Tom**, Seafood Extension Program Manager at UC Davis, was recognized as a Fellow of the Institute of Food Technologists (IFT) for outstanding contributions in the field of food science and technology, and for her service to IFT.

• **Raul H. Piedrahita** received the Outstanding Paper Award presented by the Aquacultural Engineering Society.

• **Jim McWilliams**, co-investigator with Keith Stolzenbach on a Sea Grant study modeling nearshore circulation, was elected a member of the prestigious National Academy of Sciences in spring 2002.

• **Michelle Wolfe** (née Brand), the 1989 Isaacs scholar, received the Society of Teachers of Family Medicine award while completing her

residency at the University of Rochester School of Medicine.

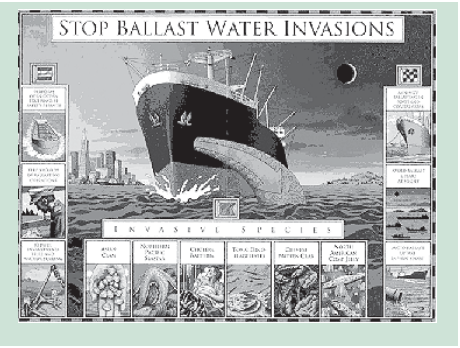
• **Kenia Whitehead**, the 1992 Isaacs scholar, received the Harold C. Bold Award from the Phycological Society of America for the innovative pre-doctoral research she conducted at the University of Washington, School of Oceanography.

• **Caren Braby,** a Sea Grant trainee with George Somero at Stanford University—Hopkins Marine Station, received the Best Student Paper Award at the Society of Integrative and Comparative Biology Conference.

• **Ayeh Bandeh-Ahmadi**, the 1998 John D. Isaacs Scholarship winner, was the recipient of the Robert L. Noland Leadership Award. This is presented by the California Institute of Technology to upperclass students who exhibit special qualities of leadership.

• California Sea Grant Marine Advisor **Susan McBride** received an award from the Humboldt County Board of Supervisors for contributions to the Redwood Coast Tsunami Workgroup.

• **Bight Bulletin** (Boletín de la Cuenca), a free bilingual newsletter featuring water quality, watersheds, and coastal habitat concerns in the California Bight, received an APEX 2002 Award of Excellence. The newsletter is a joint effort of the San Diego Association of Governments and California Sea Grant, with additional support from the Commission for Environmental Cooperation, and the Dirección General de Ecologiá Estatal de Baja California.



• The West Coast Ballast Water Outreach Project poster created by **Jodi Cassell,** California Sea Grant Marine Advisor for the San Francisco Bay counties, earned first place in the posters, flyers and t-shirts category from the National Association of Government Communicators 2001 awards program.

• Award of Distinction from the International Communicator Awards 2002, Print Media Division for Writing/Feature Story for projects that exceed industry standards in communicating a message or idea went to "Fish Production of Artificial Reef to be Studied," by **Christina S. Johnson**, California Sea Grant science writer.

participating institutions...

CalBio Marine Technologies
R/MP-86 Sea Grant Technology Program: Antiviral Drugs for Marine Bacteria ..... B. Javor, J. Trischman

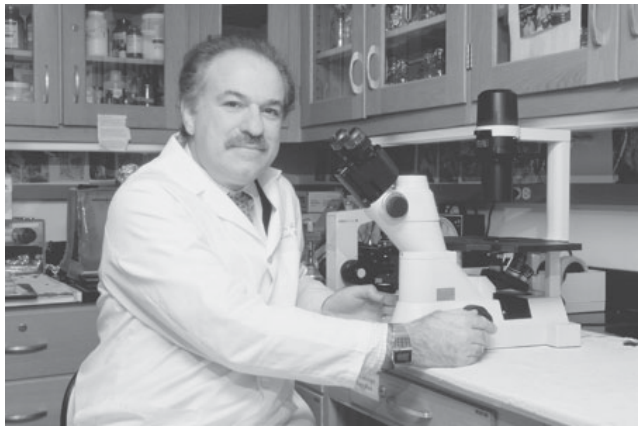
California Sea Grant Extension Program
A/EA-3 West Coast Ballast Outreach Project ..... J. Cassell, K. Hart
R/M-61PD Seeking Common Ground: Facilitating Discussions on Sea Otter and Marine Resource Issues in California ..... J. Richards

California State University, Fullerton
R/CZ-63PD Identifying the Potential of Aquarium Seaweeds in Changing Southern California Coastal Waters ..... S. Murray

California State University, Long Beach
R/CZ-151 Eradicating *Arundo donax* from California Ecosystems: Establishing the Most Effective Timing for Mechanical and Chemical Procedures ..... A. Wijte
R/CZ-163 Aquatic Nuisance Species Research and Outreach: Combating *Arundo donax* and Other Rhizomatous, Aquatic and Estuarine Nuisance Grasses by Exploiting Their Ecophysiological Characteristics ..... A. Wijte

Humboldt State University
R/CZ-155 Ecosystem and Restoration Analysis of the Smith River Estuary, California, with Emphasis on Anadromous Salmonids ..... T.J. Mulligan et al.
R/F-187 California's Dungeness Crab: Conserving the Resource and Increasing the Net Economic Value of the Fishery ..... D.G. Hankin et al.

Midwestern University
R/MP-83 Neuroinflammation, Microglia, and Marine Natural Products ..... A.M. Meyer



With Sea Grant funding, Dr. Alejandro Mayer studied a marine natural product that may help treat head injuries, multiple sclerosis, and Alzheimer's disease. Photo: Midwestern University

Pepperdine University
R/CZ-81PD Does Beach Grooming Harm Grunion Eggs? ..... K. Martin

San Diego State University
R/F-188 Fisheries Habitat: Recruitment, Growth, and Survival of Coastal Fishes on an Experimental Artificial Reef ..... T. Anderson

San Francisco Estuary Institute
R/CZ-159 Aquatic Nuisance Species Research and Outreach: Testing Ballast Water Treatment at a Municipal Wastewater Treatment Plant: Assessing Effectiveness, Limiting Factors and Cost ..... A.N. Cohen et al.

San José State University/Moss Landing Marine Laboratories
R/CZ-144 Domoic Acid Biosynthesis in Marine Diatoms: Biochemical Pathways and Environmental Regulation ..... G.J. Smith
R/CZ-161 Aquatic Nuisance Species Research and Outreach: Post-Invasion Genetic Structure of European Green Crab Populations on the U.S. West Coast and Its Implications for Their Control ..... J.B. Geller

R/F-176 Radiometric Age Validation of Two Deep-Water Fishes: The Yelloweye (*Sebastes ruberrimus)* and Blackgill (*S. melanostromus*) Rockfishes ..... G.M. Cailliet, K.H. Coale
R/F-181 Fisheries Habitat: Characterization of the California Continental Margin: Identification, Quantification and Synthesis of Existing Information ..... H.G. Greene, R. Kvitek
R/F-182 Radiometric Age Validation and Demographic Analysis of Commercially Important, Long-Lived Rockfishes ..... G.M. Cailliet, K.H. Coale
R/CZ-77PD Reconstructing the 82-Year Record of Sea Surface Temperature at Pacific Grove, California ... L.C. Breaker, W.W. Broenkow

Stanford University/Hopkins Marine Station

R/MP-79 Molecular and Biochemical Characterization of Microbial Symbionts and Their Bioactivities in Sepiod and Loliginid Squids ..... D. Epel
R/MP-89 Environmental Effects on Anti-Microbial Activity of Bacterial Symbionts in the Reproductive System of Squid ..... D. Epel
R/F-185 Migratory Movements of Pacific Bluefin Tuna Off California ..... B.A. Block, C. Farwell

Southwest Fisheries Science Center

R/M-2 Egg and Larval Production from Marine Ecological Reserves ..... R.D. Vetter et al.

The Scripps Research Institute

R/MP-90 Expression of Recombinant Proteins in Microalgae ..... S.P. Mayfield, S.E. Franklin

University of California, Berkeley

R/OE-36 Wave Climate Risk Analysis: Seasonal Triple Annual Maximum Frequency Analyses, with Intensity-Duration-Frequency Summaries ..... R.J. Sobey
R/MA-40 The New Regionalization in International Fisheries Law and Management ..... H.N. Scheiber
R/CZ-170 Observation and Physical Fluxes Between an Estuary and the Ocean ..... M.T. Stacey, T.M. Powell
R/E-59PD MarBEC MSURF Summer Undergraduate Research Program at UCB ..... J.D. Keasling
R/E-68PD MarBEC MSURF Summer Undergraduate Research Program at UCB ..... J.D. Keasling

University of California, Davis

R/CZ-154 Characterizing Vegetation–Hydrology Interactions for Tidal Marsh Restoration ..... T.C. Foin et al.
R/CZ-158 Initial Steps Toward Eradication of Alien Cordgrass from California Waters ..... D.R. Strong et al.
R/CZ-168 Environmental Marine Biotechnology: Development of Molecular and Cellular Tools for the Detection of Environmental Endocrine Disruption in Aquatic Invertebrates ..... M.J. Snyder et al.
R/CZ-169 Environmental Marine Biotechnology: Molecular and Bioassay-based Investigation of Bivalves as Transmission Vectors of Protozoal Encephalitis in Southern Sea Otters ..... P.A. Conrad et al.
R/CZ-176 Dynamics and Ecosystem Threats of Bidirectional Cordgrass Hybridization in San Francisco Bay ..... D.R. Strong

An example of *Spartina alterniflora* hybrids found in fragment marshes in highly urbanized areas, such as San Francisco's India Basin. Photo: Invasive *Spartina* Project

R/A-108 Biotechnological Techniques to Improve Crustacean Aquaculture ..... M.J. Snyder, E.S. Chang
R/A-109 Preservation of Genetic Variation Within Aquacultural Stocks of the White Sturgeon ..... B.P. May
R/A-111 Collaborative Studies with the University of Hawaii: Studies Addressing the Growth-Stimulating Potential of Recombinant Bovine Growth Hormone in the Aquaculture of Tilapia and Shrimp ..... E.S. Chang, T.B. Hayes
R/A-114 Control of Rickettsial Infections in White Seabass (*Atractoscion nobilis*) ..... R.P. Hedrick, K.D. Arkush
R/A-116 Development of a Recirculation System and Diet for the Culture of California Halibut (*Paralichthys californicus*) ..... R.H. Piedrahita, D.E. Conklin
R/A-117 Characterizing the Role of Environmental Stressors in the Development of Withering Syndrome in Red Abalone ..... R.S. Tjeerdema et al.
R/F-177 Molecular Genetic Analysis of Recruitment Patterns in the Dungeness Crab, *Cancer magister* ..... R.K. Grosberg
R/F-179 Spatial Management of Fisheries ..... J.E. Wilen et al.
R/F-184 Quantifying and Minimizing Risk That Hatchery-Enhancement Will Reduce Genetic Diversity of White Seabass ..... D. Hedgecock
R/MA-41 Building Marine Policy Analysis Capabilities in California ..... J.E. Wilen, L.W. Botsford
R/W-75PD International *Caulerpa taxifolia* Workshop: Research, Management, and Outreach ..... E.D. Grosholz
R/CZ-62PD Environmental Constraints of *Caulerpa taxifolia* (Putative) in California. ..... S.L. Williams

University of California, Irvine

R/C-46PD Detection of Human Viruses and Male-Specific Coliphages in Coastal Waters of Southern California ..... S. Jiang

University of California, Los Angeles

R/CZ-152 Identification of Natural and Synthetic Peptides for Controlling Marine Larval Set ..... R.K. Zimmer
R/CZ-153 Quantitative PCR Assay for Marine Bacteria ..... C.F. Brunk

A juvenile white seabass. Photo: Hubbs-SeaWorld Research Institute, San Diego, California

R/ CZ-156 Integrated Modeling of the Southern California Coastal Ocean: Biogeochemistry and Particulate Dynamics ..... K.D. Stolzenbach, J.C. McWilliams
R/CZ-167 Sea Grant Technology Program: PCR Quantitative Assay for Marine Bacteria ..... C. Brunk
R/CZ-171 Modeling of Water and Sediment Quality in Impacted Coastal Embayments ..... K.D. Stolzenbach, J.C. McWilliams
R/CZ-175 Fate and Transport of Planar and Mono-Ortho Polychlorinated Biphenyls and Polychlorinated Napthalenes in Southern California Sediments ..... M.I. Venkatesan
R/MP-93 Novel Post-Translationally Modified Peptide Antibiotics from Solitary Tunicates ("Sea Squirts") ..... R.I. Lehrer et al.
R/W-76PD Workshop on Educating California Coastal and Ocean Management ..... G. Hodgson

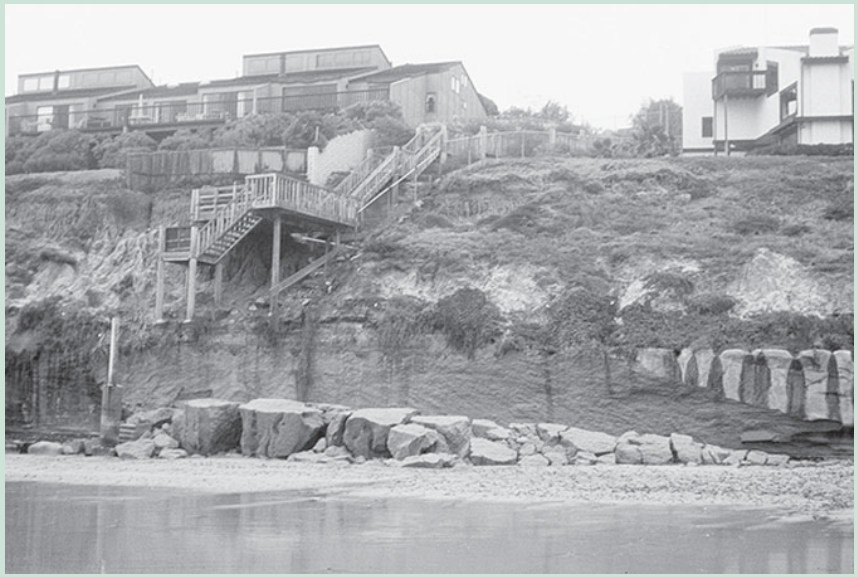
University of California, Los Angeles Marine Center

R/E-71PD Urban Youth and the Ocean ..... S. Strand, C. Koconis
R/E-86PD Urban Youth and the Ocean ..... S. Strand, C. Campbell

University of California, San Diego

R/A-107 Genetic Engineering to Create a Transformed Oyster Cell Line ..... J.C. Burns
R/A-113 Sea Grant Technology Program: Genetic Engineering of a Shrimp Cell Line with Pantropic Retroviral Vectors ..... J.C. Burns, K. Klimpel

R/OE-37 Mitigation of Coastal Bluff Instability in San Diego County, California ..... S.A. Ashford



Homes built on actively eroding bluffs in San Diego County are no longer fully supported from below, making them vulnerable to landslides and earthquakes. Photo: California Sea Grant archives

University of California/Scripps Institution of Oceanography

R/CZ-150 Contrasting Effects of Ecosystem Alteration by Two Exotic Wetland Invertebrates ..... L.A. Levin

R/CZ-164 Alongshore Coherence of Nearshore Temperature Variability ..... J.L. Largier

R/CZ-165 Improving Ecosystem-Level Function of Artificial Armored Shorelines ..... L.A. Levin et al.

R/CZ-166 Surf-zone Drifters: A New Tool for Observing Nearshore Circulation ..... R.T. Guza

R/CZ-172 Exploring the 1990s: Investigation Into Factors Controlling Siliceous Microplankton Distribution in the Santa Barbara Channel ..... E.L. Venrick, C.B. Lange

R/CZ-173 Recovery of Trophic Function in a Restored Pacific Coastal Wetland ..... L.A. Levin, C. Currin

R/CZ-177 The San Diego–La Jolla Ecological Reserve: Implications for the Design and Management of Marine Reserves ..... P.K. Dayton, E. Sala

R/F-178 Patterns of Recruitment in Red Sea Urchins: A Population Genetics Approach ..... R.S. Burton

R/F-180 Pelagic Fish Egg Abundance and Mortality Estimation by CUFES and Real-Time Machine Vision ..... D.M. Checkley, M.M. Trivedi

R/MP-77 Marine Natural Materials: Novel Biological Elastomers from Marine Organisms ..... R.E. Shadwick

R/MP-84 Sea Grant Technology Program: Cloning and Expression of Bryostatin Synthesis Genes and Combinatorial Biosynthesis of Novel Bryostatins ..... M.G. Haygood et al.

R/MP-87 The Biomedical Potential of California Marine Organisms ..... D.J. Faulkner

R/MP-88 Investigation of Anti-cancer Compounds in the Marine Bryozoan, *Bugula pacifica* ..... M.G. Haygood

R/MP-91 Marine Natural Materials: Novel Biological Elastomers from Marine Invertebrates ..... R.E. Shadwick, H. Waite

E/G-12PD An Atlas of Ocean Productivity ..... W.H. Berger

R/AS-64PD Preventing the Spread of the Tropical Alga *Caulerpa taxifolia* in Southern California Through Outreach and Public Education ..... E. Sala

R/CZ-57PD Restoration of Coastal Wetlands: Colonization Enhancement and Evaluation of Trophic Function ..... L.A. Levin

R/CZ-60PD California Current Zooplankton: Test for Interdecadal Variation in Size Composition ..... M. Mullin

University of California, Santa Barbara

R/MP-69 Polyunsaturated Fatty Acid Oxidases in Marine Algae ..... A. Butler

R/MP-76 Marine Enzymes and Siderophores: A Biochemical and Bioorganic Approach to Marine Pharmacology ..... A. Butler

R/MP-81 Marine Inflammation Research Program 1. Pharmacological and Biochemical Studies of Inflammatory Processes ..... R.S. Jacobs

R/MP-82 New High-Performance Composite Materials from Marine Biomineralization ..... D.E. Morse

R/MP-85 Sea Grant Technology Program: Pharmacological Adaptation of Protoctista as Novel Models to Study Inflammation ..... R.S. Jacobs

R/MP-92 New High-Performance Nanocomposite Materials from Marine Biomineralization: Biotechnological and Interdisciplinary Approach ..... D.E. Morse
R/CZ-160 Aquatic Nuisance Species Research and Outreach: Evaluating the Health Risk Posed by the Invasive Chinese Mitten Crab .... J.E. Dugan
R/CZ-162 Aquatic Nuisance Species Research and Outreach: Biological Control of Invasive Green Crabs: A New, Rapid and Reliable Safety Test of a Proposed Control Agent ..... A.M. Kuris, J.H. Goddard
R/CZ-174 Ecological Impacts of Beach Grooming on Exposed Sandy Beaches ..... J.E. Dugan et al.
R/CZ-178 Linking Early Fish Growth and Transport to Circulation Using Otolith Microstructure and Microchemistry ..... M.S. Love et al.
R/F-183 Assessment of the Reproductive Potential of Nearshore Rockfish and the Impact of Environmental Conditions ..... P.M. Collins
R/MP-67PD The Physiology of Wound Plug Formation in *Dascladus vermicularis*. ..... R.S. Jacobs
R/E-54PD Translating Research into K-12 Education: Genuine Research Experiences for Pre-college Students and Sharing with Classmates, Teachers, and Families ..... M. Polne-Fuller

High-school students participating in a summer program at the University of California, Santa Barbara collect data on fish populations living in a local wetland. Photo: Miriam Polne-Fuller, UC Santa Barbara

R/F-59PD Potential Fecundity and Realized Reproductive Output in the Grass Rockfish, *Sebastes rastrelliger* ..... P.M. Collins

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R/CZ-142 Direct In Vivo Measurements of Enzyme Reaction Rates in Red Abalone as Indices of Sublethal Toxic Effects ..... R.S. Tjeerdema
R/F-186 Assessing the Impacts of Climate Change on the California Squid Fishery: An Integrated Ecosystem Approach ..... B.B. Marinovic et al.
R/MA-39 Socioeconomic Organization of the California Market Squid Fishery: Assessment for Optimal Resource Management ..... C. Pomeroy, M. FitzSimmons
E/UG-5 Assessing Sanctuary Shorelines: A Role for High School Students in Resource Management ..... J.S. Pearse, P. Levin
E/UG-6 Assessing Sanctuary Shorelines: A Role for Volunteers, Particularly High School Students, in Resource Management ..... J.S. Pearse, J.B. Heffington
R/CZ-69PD Quantitative Assessment of Marine Protected Areas for Abalone Restoration in Southern California ..... L. Rogers-Bennett

University of Hawaii

W98-3PD 9th Pacific Congress on Marine Science and Technology (PACON 2000), The Pacific Century ..... N. Saxena
W01-13PD 9th Taxonomy of Economic Seaweeds Workshop ..... K. McDermid

University of Washington

R/A-112 National Oyster Research Program: Toward the Genetic Engineering of Disease Resistance in Oysters ... C.S. Friedman, J.C. Burns
R/A-115 Tools for Management of Withering Syndrome in Abalone, *Haliotis* spp.: PCR Detection and Feed-Based Therapeutic Treatment ..... C.S. Friedman

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