Sea Grant
California

Project Profiles

2002

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"Science Serving California's Coast"

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California Sea Grant has begun creating a series of one-page summaries of funded research, education and extension projects. The following are currently available on our Web site at **www.csgc.ucsd.edu**.

Project Leader	Project No.	Dates	Title
AQUACULTURE			
Chang	R/A-111	1999–2002	Accelerating Growth Rates in Shellfish with Bovine Growth Hormone
May	R/A-109	1998–2001	Developing a Breeding Plan for Farm-Raised Sturgeon
AQUATIC NUISANCE SPECIES			
Kuris	R/CZ-162	1999–2001	An Investigation of a Biological Control Agent for the Green Crab
Levin	R/CZ-150	1998–2000	Alteration of Wetland Habitat by Two Exotic Invertebrates
Wijte	R/CZ-151 & R/CZ-163	1998–2001 1999–2002	Combating *Arundo Donax* and Other Nuisance Grasses
COASTAL OCEAN			
Brunk	R/CZ-153 & R/CZ-167	1998–2000 2000–2002	Developing New Techniques for Evaluating Human Fecal Water Contamination
Dayton	R/CZ-141	1998–2000	Determining the Processes that Control Kelp Spore Abundance
Griggs	R/CZ-157	1998–1999	Coastal Cliff Erosion in San Diego County
Hering	R/CZ-146	1998–2000	A Better Method for Evaluating Heavy Metal Water Pollution
Jiang	R/C-46PD	1999–2000	Detection of Human Viruses in Coastal Waters of Southern California
Silver	R/CZ-145	1998–2000	Understanding Domoic Acid and Toxic Diatom Blooms
Smith	R/CZ-144	1998–2000	Domoic Acid in Marine Diatoms: Biochemical Pathways and Environmental Regulation
Stacey	R/CZ-170	2001–2004	Monitoring the Fluxes of Salinity, Pollution and Phytoplankton into the San Francisco Bay
Stolzenbach & McWilliams	R/CZ-171	2001–2004	Modeling Water and Sediment Quality in Two California Bays
Tjeerdema	R/CZ-142	1998–2001	Sublethal Toxic Effects of Water Pollution on Red Abalone
Venkatesan	R/CZ-175	2001–2003	Fate and Transport of Planar and Mono-Ortho Polychlorinated Biphenyls and Polychlorinated Napthalenes in Southern California Sediments
Wright	R/CZ-136	1997–1999	Predicting Flows in Semi-Arid Watersheds Using GIS Technologies
Zimmer	R/CZ-152	1998–2001	Finding the Chemical Signals that Induce Marine Larvae to Settle to the Sea Floor
EDUCATION			
Berger	E/G-12PD	1998-2000	Innovative Tools for Educators: An Interactive Online Atlas of Ocean Productivity

Education (continued)

Pearse	E/UG-5PD	2000–2001	Assessing Sanctuary Shorelines: A Role for High School Students in Resource Management
Polne-Fuller	R/E-54PD	1998–2000	Encouraging Learning Through an Exploration of the Sea
Strand	R/E-71PD	2001	Supporting an Educational Marine Science Camp for Urban Youth

Fisheries

Burton	R/F-170	1997–1999	Recruitment Patterns in Red Sea Urchins: A Population Genetics Approach
Cailliet	R/F-174	1998–1999	Validating Age Estimates for Bocaccio Rockfish with Radiometric Dating
Friedman	R/F-43PD	1998–2000	First Known Sightings of the Withering Syndrome Bacterium Discovered North of San Francisco

Fisheries Habitat

Greene & Kvitek	R/F-181	2000–2001	Characterizing Fisheries Habitat Along the California Continental Margin

New Marine Products

Epel	R/MP-79 & R/MP-89	1998–2001 2000–2002	Frontiers in Squid Reproduction: Prospecting for New Antibiotics
Mayer	R/MP-73	1995–2000	Neuroinflammation, Finding A Marine Natural Product that Targets Microglia in Brain

Ocean Engineering

Sobey	R/OE-36	1998–2001	Wave-Climate Risk Analysis: Predicting the Size, Frequency and Duration of Large Wave Events

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California Sea Grant

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Berger, E/G-12PD

Brunk, R/CZ-153 and R/CZ-167

Burton, R/F-170

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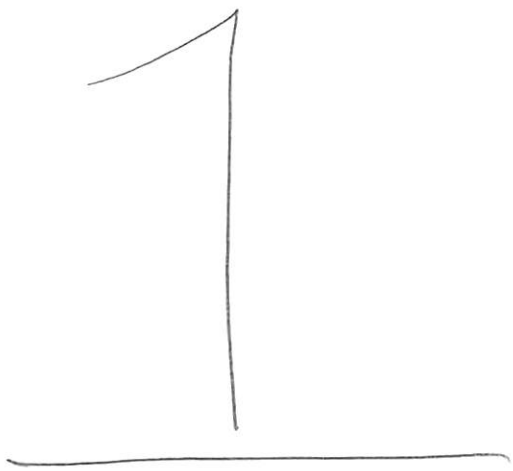
Zimmer, R/CZ-152



R/A-109: 3.1.1998–3.32.2001

Developing a Breeding Plan for Farm-Raised Sturgeon

Bernard May
University of California, Davis

Summary

Genetics professor Dr. Bernie May of the University of California at Davis and Sea Grant Trainee Dr. Jeff Rodzen were funded to develop a breeding program for broodstock at Stolt Sea Farm, the state's largest producer of white sturgeon caviar.

The goal of the project was twofold: to develop a breeding plan for slowing the rate of inbreeding of offspring and to investigate whether commercially desirable traits—superior growth rates, enhanced caviar yield and early sexual maturity—can be selectively bred.

White sturgeon are naturally slow-growing, late maturing, long-lived fish. Females, for instance, do not reach reproductive maturity until age 6 or 7. These traits make sturgeon a time-intensive, expensive fish to farm. Nonetheless, California's farm-raised caviar production has seen steady growth with declines in wild sturgeon stocks. Whereas eight years ago, California's sturgeon farms were producing caviar on a primarily experimental basis, in 2000, California produced approximately one-tenth of what was caught from the Caspian Sea region that year. California is the only state in the country that is currently farming sturgeon for caviar. It has four farms.

Method

For the project, the scientists first identified and characterized DNA markers that allowed them to identify individual sturgeon. They then used these genetic fingerprints to identify kinship relationships among all the members of the broodstock. In separate experiments, they looked for characteristics that appear to be inherited. For instance, they studied the degree to which body size (weight and length) is correlated with dam and sire body size. They also examined the inheritability of a variety of caviar characteristics, including weight, grade, color, firmness and yield.

White sturgeon, like the one above, can reach gargantuan proportions. Such large catches today, however, are rare. The white sturgeon is native to the San Francisco Bay–Delta and estuaries of the Pacific Northwest. Photo: University of California, Davis.

Findings

Body length and weight were shown to have a strong genetic component, while caviar weight was influenced predominantly by environment. Caviar yield, however, was moderately correlated with the size of the female.

Applications

By mapping the pedigree structure of a commercially viable sturgeon broodstock, the scientists provide the scientific foundation for selectively breeding sturgeon in the future. Because pedigree information also makes it possible to avoid breeding siblings and cousins, the work can be used to slow inbreeding. This in turn reduces the need to replenish broodstocks with fish caught from the wild.

Stolt Sea Farm is continuing to gather data on caviar characteristics in order to document more completely the role of genetics in caviar quality and yield.

A beluga sturgeon harvested from the Caspian Sea region, traditionally the source of the world's premier caviars. Poaching, environmental degradation and overfishing have led to a near collapse of all sturgeon populations in the Caspian Sea region. The "Caviar Emptor: Let the Connoisseur Beware" campaign is an example of the growing public awareness of Russian and beluga caviar shortages. Photo: University of California, Davis.

Cooperating Organizations

Stolt Sea Farm California LLC
The Fishery, Inc.
UC Davis Aquaculture and Fisheries Program—Aquatic Center Facility

Publications

McQuown, E.C. 2000. Inheritance of microsatellite loci and delineation of lake sturgeon (*Acipenser fulvescens*) population ogenetic structure. M.S. thesis abstract, University of California, Davis.

McQuown, E.C., B.L. Sloss, R.J. Sheehan, J. Rodzen, G.J. Tranah, and B. May. 2000. Microsatellite analysis of genetic variation in sturgeon: New primer sequences for *Scaphirhynchus* and *Acipenser*. *Trans. Am. Fish. Soc.* 129:1380–1388.

Presentations

Rodzen, J., B.P. May, and T.R. Famula. Combining molecular genetics with traditional animal breeding: the white sturgeon as a case study. Invited speaker, California Aquaculture Association Annual Meeting, March 2001, Sacramento, California.

Rodzen, J., B.P. May, and T.R. Famula. Use of microsatellite markers in a commercial breeding plan for white sturgeon. Aquaculture Symposium, Plant and Animal Genome Conference, January 2001, San Diego, California.

Rodzen, J., B.P. May, and T.R. Famula. Use of microsatellite markers in a commercial breeding plan for white sturgeon. White Sturgeon Symposium workshop, September 2000, Davis, California.

Trainee and Thesis

Rodzen, Jeff, Ph.D., Department of Animal Sciences, University of California, Davis, 2001, "Preservation of Genetic Diversity Within Aquaculture Stocks of White Sturgeon."

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R/A-111: 3.1.1999–2.28.2002

Accelerating Growth Rates in Shellfish with Bovine Growth Hormone

Ernest Chang
University of California, Davis—Bodega Marine Laboratory

Summary

Marine biologist Dr. Ernest Chang of the Bodega Marine Laboratory and colleagues at the University of Hawaii investigated the possibility of using bovine growth hormone to increase growth rates of American lobster (*Homarus americanus*) and two species of shrimp—a cold-water California rock shrimp (*Sicyonia ingentis*) and the warm-water *Penaeus vannamei*.

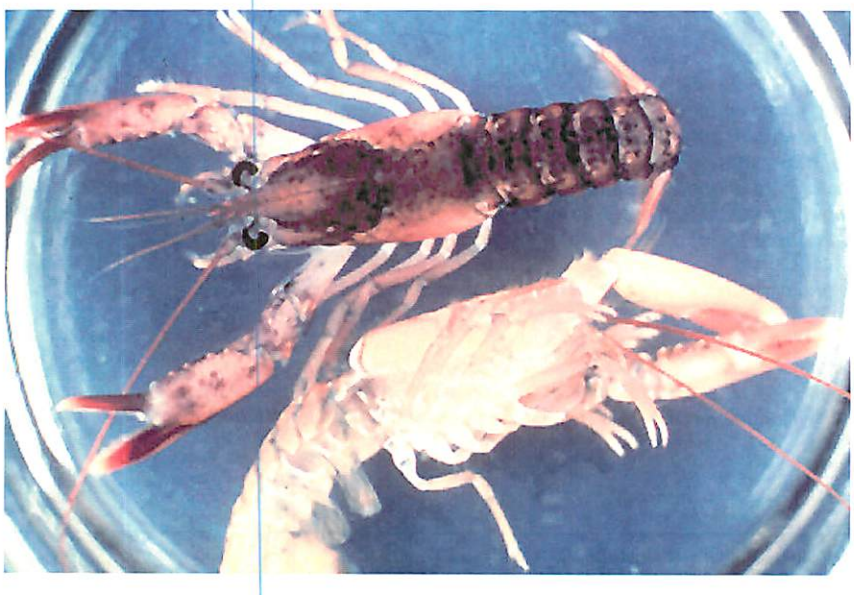
In previous work, Dr. Chang was able to increase growth rates in shrimp by as much as 50 percent by surgically manipulating the animals' glands or by injecting them with hormones. Although these methods are not suited for commercial use, they do show the potential for dramatically enhancing growth rates and lowering shellfish production costs. Because some species may metabolize food more efficiently when on hormones, hormone supplements could also reduce nitrogen waste at fish farms.

Findings

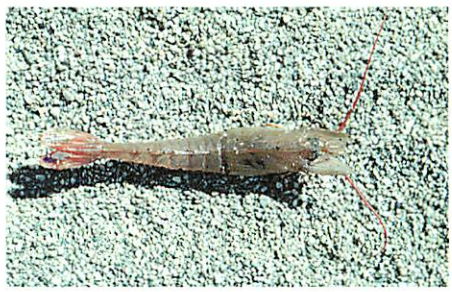
Though their findings are preliminary, the researchers' experiments suggest that the shellfish are relatively unaffected by bovine growth hormone. In a series of experiments, neither cold-water shrimp nor American lobster specimens responded to hormone supplements. In one trial, warm-water shrimp specimens grew about 25 percent faster.

Background

Seafood imports represent the single largest component of the nation's agricultural trade deficit. About $9-billion-worth of seafood is imported each year. As a percentage, about 60 percent of all seafood consumed each year comes from abroad.



An American lobster (*Homarus americanus*). The photo shows a recently shed exoskeleton and a larger, newly molted animal. Photo: University of California, Davis.



A cold-water California shrimp (*Sicyonia ingentis*). Experiments suggest this species does not respond to bovine growth hormone in feed. Photo: University of California, Davis.

The Department of Commerce looks to aquaculture as the future of domestic fish production. In the next 25 years, it is targeting a fivefold increase in the value of domestic aquaculture products—from $1 billion a year in 2000 to $5 billion in 2025. To accomplish this will require improved production systems, strategies and husbandry practices.

Bovine growth hormone is a synthetic hormone fed to cows to increase milk production. The Food and Drug Administration and the Environmental Protection Agency have approved the hormone as safe for human consumption and the environment.

Cooperating Organizations

Monsanto Corporation
University of Hawaii

Publications

Chang, E.S. 2001. Crustacean hyperglycemic hormone family: Old paradigms and new perspectives. *Amer. Zool.* 41:380–388.

Stentiford, G.D., E.S. Chang, S.A. Chang, and D.M. Neil. 2001. Carbohydrate dynamics and the crustacean

hyperglycemic hormone (CHH): Effects of parasitic infection in Norway lobsters (*Nephrops norvegicus*). *Gen. Comp. Endocrinol.* 121:13–22.

Peeke, H.V.S., G.S. Blank, M.H. Figler, and E.S. Chang. 2000. Effects of exogenous serotonin on a motor behavior and shelter competition in juvenile lobsters (*Homarus americanus*). *J. Comp. Physiol.* 186:575–582.

Chang, E.S., S.A. Chang, B.S. Beltz, and E.A. Kravitz. 1999. Crustacean hyperglycemic hormone in the lobster nervous system: Localization and release from cells in the subesophageal ganglion and thoracic second roots. *J. Comp. Neurol.* 414:50–56.

Presentations

Stress indicators in lobsters: Hormones and heat shock proteins. 2nd Annual Long Island Sound Lobster Health Symposium, Ronkonkoma, New York, November 2001.

Hormonal Regulation of crustacean growth, development, reproduction, and response to stress. California Marine Research and Cooperative Extension Conference. Sacramento, California, May 2001.

Hormones in the lives of crustaceans: An overview. Annual Meeting of the Society for Integrative and Comparative Biology. Chicago, Illinois, January 2001.

Endocrinology of lobster molting and stress. University of Oregon Institute of Marine Biology, Charleston, Oregon, October 2000.

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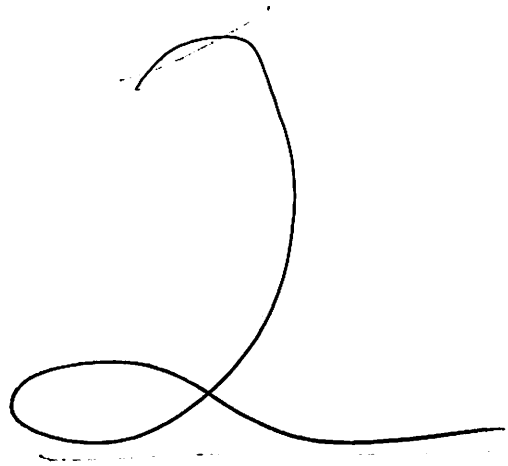


R/CZ-162: 10.1.1999–9.31.2001

Aquatic Nuisance Species: An Investigation of a Biological Control Agent for the Green Crab

Armand Kuris
University of California, Santa Barbara

Background

Since their first sighting in San Francisco Bay in 1989, European green crabs (*Carcinus maenas*) have undergone what can truly be called a population explosion. In 11 years, they have spread south to Morro Bay and north to British Columbia, Canada. Untold millions now live under rocks in mud-bottomed areas of the state's estuaries. Although they have not yet become established on the outer shoreline—perhaps because they cannot tolerate heavy wave action—some biologists believe it is just a matter of time before they spread to the coast.

Because green crabs eat native shellfish and small crustaceans, including juvenile Dungeness crabs, green crabs threaten to further stress California's estuarine ecosystems.

Biologists looking at strategies for eradicating the crabs note that California's green crabs are larger and more numerous than their relatives in Europe. One reason may be the absence in California of the crab's native parasites.

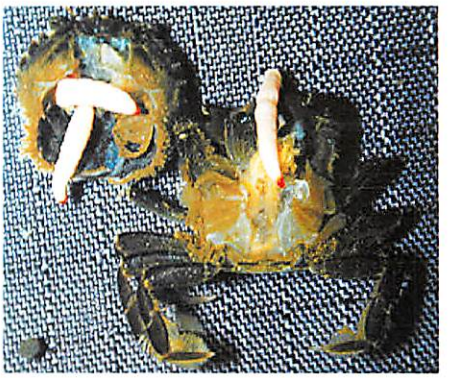
The Project

Dr. Armand Kuris of the University of California, Santa Barbara was funded to investigate the feasibility of using the parasite *Sacculina carcini*, a barnacle, as a "biological control agent" for reducing green crab numbers.

Findings

Dr. Kuris' experiments showed that *Sacculina carcini* infects not only green crabs but also native shore crabs. The pathology of the barnacle is markedly different in the two crabs, however. Whereas the parasite blocks reproduction in green crabs but is never lethal to its host, the parasite is always fatal to shore crabs. Even though the parasite cannot complete its life cycle in shore crabs, the fact that it can infect them at all makes the parasite a poor candidate for release in the wild.

The European green crab is just one of many aquatic nuisance species to have invaded degraded habitats along the coast. Photo: University of California, Santa Barbara.



Green crabs infected with parasitic worms. Photo: University of California, Santa Barbara.

In the second part of the project, Dr. Kuris and colleagues went to Great Britain in search of other, more host-specific, green crab parasites. They found one that shows promise: a rose-colored flatworm with a bright crimson head. The flatworm (*Fecampia erythrocephala*) infects small shore crabs, at maturity bursting through their exoskeletons. Because most reports on the worm's biology predate the 1950s, the scientists decided to document its habitat distribution, abundance, host specificity and its effect on host growth. Their work suggests that the worm is an important contributor to crab mortality in Europe. To further evaluate its potential as a biological control agent in the United States, the scientists recommend that future work focus on the flatworm's host specificity.

Cooperating Organizations

Centre for Research on Introduced Marine Pests, Australia
Universidade da Coruna, Spain
Universidade de Evora, Portugal
University of Copenhagen

University of New Hampshire
University of Oregon

Publications

Kuris, A.M., and K.D. Lafferty. 1999. Can biological control be developed as a safe and effective mitigation against established introduced marine pests? In: Proceedings, 1st International Marine Bioinvasions Conference, January 1999, Boston, Massachusetts.

Presentations

Annual Meeting of Pacific Coast Shellfish Growers Association, Warm Springs, Oregon, October 2000.

92nd Annual Meeting of the National Shellfish Association. and Green Crab Workshop, Seattle, Washington, March 2000.

Annual meeting of the Western Society of Naturalists, Monterey, California, December 1999.

International Organization for Biological Control Symposium, Montpellier, France, November 1999.

Trainee and Thesis

Torchin, Mark E., Ph.D. in Ecology, Evolution and Marine Biology, University of California, Santa Barbara, anticipated September 2002, "Role of Parasites in the Invasion Success of Exotic Species."

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Sea Grant California

COASTAL OCEAN RESEARCH

R/CZ-150: 3.1.1998–10.30.2000

Alteration of Wetland Habitat by Two Exotic Invertebrates

Lisa Levin

University of California, San Diego—Scripps Institution of Oceanography

Background

California has lost more than 90 percent of its wetlands. The remaining 10 percent now support about 41 percent of the state's rare and endangered plant and animal species. Historically, wetlands have been destroyed by urbanization, dams, and other projects for flood control and irrigation. More recently, they have been plagued by exotic species. In the bustling San Francisco Bay area, for example, hybrids of the nonnative invasive grass *Spartina alterniflora* have converted tidal mud flats into grassy areas, destroying rest stops for migratory birds on the Pacific flyway. Further, loss of wetlands and marshes could impact not only protected species such as the Belding's Savannah sparrow and tidewater gobi, but also commercial fisheries. Even beach erosion could be exacerbated, since healthy lagoons are a source of beach sand.

The Project

Although California's wetlands are known to be vulnerable to exotic invasions, few studies have sought to evaluate, in detail, the ecological consequences of nonnative species. The purpose of this study was to examine closely the effects of the mat-forming Asian mussel (*Musculista senhousia*) and the burrowing Australian isopod (*Sphaeroma quoyanum*) on natural and re-created marshlands and tidal flats in Mission Bay in San Diego, San Diego Bay, and San Francisco Bay.

Asian mussels form dense mats, displacing native clams. Photo: Scott Rumsey.

For the project, scientists led by Dr. Lisa Levin, a professor of biology at Scripps Institution of Oceanography, measured the percent area covered by each of the two invasive species. They then measured the density of isopod burrows and the strength and slope of marsh banks. Isopod burrows were visualized with x-radiography. Wax casts of the burrows were also made. Much of the mussel work focused on looking at how the filter feeders change sediment quality and how their shells alter bottom environments and marine life.

Findings

Among their findings, they observed that isopod burrows undercut marsh banks, increasing erosion and sediment loss by as much as 250 percent. Marsh bank erosion rates were observed to exceed one meter per year at one site. They also found that the slope of a marsh bank influences the ability of the isopod to invade. Isopods only thrive on steep vertical faces.

The mussels were shown to alter their environment, but through a very different mechanism. With them, changes are caused by their tiny shells, which trap fine-grained sediments that otherwise would remain suspended in the water column. As a result, the mussels effectively convert sand flats into mud flats. Another finding: the mussels were more common in restored marshes than in natural ones, suggesting that re-created marshes may function as "disturbed" habitat.

A collapsed marsh bank in San Francisco Bay, caused in part by the presence of burrowing isopods. Photo: Jeff Crooks.

In conclusion, Dr. Levin reported that while the mussels and isopods cause significant physical changes to wetlands, "scores of other invaders present in California bays and estuaries are having demonstrable ecological effects as well."

Applications

From a management perspective, Dr. Levin thinks her work has applications for building and restoring wetlands with a better ability to resist invasion by the Australian isopod. Her work suggests that the

way to do this is to build sloping marsh-bank channels, inhospitable to the isopod.

Findings from this project have been incorporated into the Port of San Diego and the Navy's long-term planning document for San Diego Bay. Reserve managers with the U.S. Fish and Wildlife Service, and the California Department of Fish and Game have also been provided with results from this project, as have the U.S. Geological Survey, Elkhorn Slough National Estuarine Research Reserve, and the San Francisco Estuary Institute.

Cooperating Organizations

California Department of Fish and Game
City of San Diego Park and Recreation
University of California Natural Reserve System
U.S. Fish and Wildlife Service

Awards

University of California, San Diego, Chancellor's Associates Award for Excellence in Research, 2000

Publications

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Graduate Trainee and Thesis

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R/CZ-151: 3.1.1998–2.28.2001 and R/CZ-163: 10.1.1999–9.30.2002

Combating *Arundo Donax* and Other Nuisance Grasses

Antonia Wijte
California State University, Long Beach

Background

Arundo donax is a cane-like, towering weed that has gained notoriety for its hearty resistance to chemical spraying and remarkable ability to become the dominant plant in low-lying areas such as the Santa Ana, Santa Margarita, Santa Clara, and Tijuana river banks.

By displacing native plants, *Arundo* and other invasive grasses, such as *Spartina alterniflora*, not only dramatically alter wild landscapes but also displace animal life. The federally protected least Bell's vireo, for instance, cannot nest in *Arundo*.

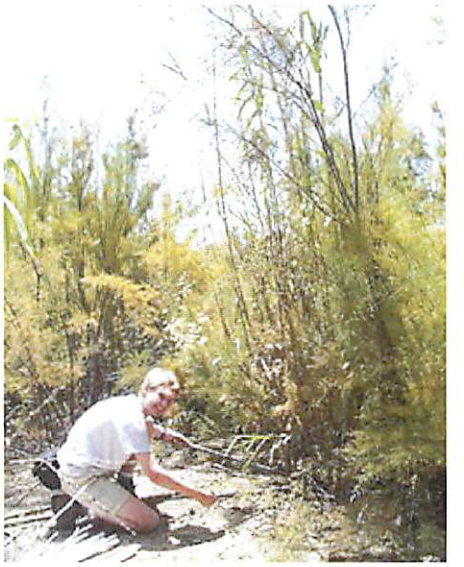
The Project

Dr. Antonia Wijte of California State University at Long Beach has conducted studies that show *Arundo* is sensitive to the timing of when herbicides such as Rodeo are applied. To understand why, it helps to know a little bit about how the plant stores energy and where. Normally, the plant's vascular system stores food throughout the plant—in its leaves, stems and roots—until the plant runs out of nitrogen, a nutrient needed to make nucleic acids, proteins, and enzymes. When this happens, the plant no longer has the nitrogen it needs for cell division and so begins to transport food to root-like structures called rhizomes. Since *Arundo* will not die unless its rhizomes are killed, the ideal time to apply herbicide occurs when the plant's nitrogen levels are depleted and food is being transported into the rhizomes.

Graduate student Christiana Chen of Cal State Long Beach sprays herbicide on *Arundo* in the Santa Margarita River in Camp Pendleton. Sea Grant research has shown that the optimal time to apply herbicide occurs when *Arundo*'s vascular system is transporting food into its root-like structures. Photo: Antonia Wijte.

Application

A goal of this project was to examine whether it is possible to measure nitrogen and carbon levels in *Arundo* leaves and then to use these measurements to optimize the timing of herbicide application. Dr. Wijte is conducting similar experiments with two other invasive rhizomatous grasses, *Spartina alterniflora* and *Phragmites australis*.



Dr. Antonia Wijte cuts stands of *Arundo*. Photo: California State Long Beach.

At present, she has funding for an outreach program in which resource managers are encouraged to send leaf samples to her lab for nitrogen and carbon analysis. Based on this analysis, she will recommend whether and when to apply herbicide. Instructions on how to take leaf samples can be found at her website.* Field comparisons have shown that leaf-nutrient analyses significantly improve eradication efforts.

Cooperating Organizations

Camp Pendleton Marine Corps Base
Center for Natural Lands Management
Mission Resource Conservation District
San Diego County
San Gabriel Mountains Regional Conservancy

Presentations

Peck, G.W., and A.H.B.M. Wijte. "Temporal variation in the nitrogen

carbon ratio in *Arundo donax* L.: Herbicide effectiveness." 15th Biennial International Conference of the Estuarine Research Federation, New Orleans, Louisiana, 1999. Poster presentation.

Motamed, E.R., and A.H.B.M. Wijte. "Optimizing the timing of mechanical eradication of *Arundo donax* L," 15th Biennial International Conference of the Estuarine Research Federation, New Orleans, Louisiana, 1999. Poster presentation.

Trainees

Peck, George W., M.S. in Biology, California State University, Long Beach, 1999.

Chen, Christiana, M.S. in Biology, California State University, Long Beach, anticipated 2002.

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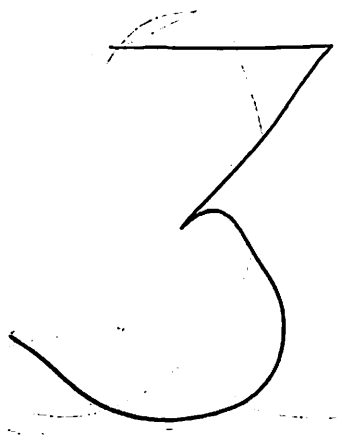

R/CZ-153: 3.1.1998–8.31.2000 and R/CZ-167: 3.1.2000–6.30.2002

Developing New Techniques for Evaluating Human Fecal Water Contamination

Clifford F. Brunk
University of California, Los Angeles

Coastal communities trying to clean up their beaches face many challenges, a significant one being the technical difficulty of accurately measuring human fecal bacteria in seawater. This problem arises because standard water tests are based on the abundance of "indicator" bacteria—not on direct measurements of the potentially most dangerous human pathogens.

Indicator counts have many fundamental limitations. For instance, they are not specific to a particular species, making it impossible to identify the source of contamination. Birds, cats, dogs, horses, seals and people all excrete fecal coliform bacteria, the most commonly used indicator bacteria. Another drawback, fecal coliform bacteria are rarely a major component of bacterial contamination.

The main advantage of using indicator bacteria is simply that these bacteria grow quickly and easily on culture plates, and they are associated with mammalian or avian feces. Many pathogens, however, do not grow in culture.

Bacteroides fragilis, for instance, constitutes as much as 30 percent of the total bacteria in human feces. But because these bacteria do not grow in culture, they are not monitored by public health officials.

Method

Biology professor Dr. Clifford F. Brunk at the University of California, Los Angeles, and colleagues isolated DNA from bacteria in water samples. They then used a polymerase chain reaction (PCR) analysis to amplify the genetic information of several small subunits of ribosomal RNA genes. From these, the scientists identified a set of nine genetic markers that made it possible to "fingerprint" the bacteria and so identify its source.

The researchers, for instance, found genetic markers that distinguish storm drain runoff from sewage effluent and human from animal feces.

PCR amplification, however, has its own limitations. It does not amplify all gene sequences equally, meaning that it may overestimate the abundance of some bacteria while underestimating the abundance of others. There are, however, ways to circumvent this limitation. One is to co-amplify nearly identical gene sequences. Another is to use DNA fingerprinting to search for the presence of certain bacteria, as opposed to taking a snapshot of the full complement of bacterial flora.

Applications

Dr. Brunk's work expands the spectrum of bacterial species that can be detected and monitored in coastal waters. Improved detection methods will make it possible to identify sources of bacterial pollution, linking contamination events to upstream sources.

Collaborations

The Orange County Water District is using Dr. Brunk's techniques to identify the organisms that

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.

are creating bothersome films on the city's water filters. Dr. Jed Fuhrman of University of Southern California is also using DNA fingerprinting to compare the assortment of bacterial flora in coastal waters around the world.

Publications

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Trainee

Moradian, Mkhitar, graduate studies in Organismic Biology, Ecology and Evolution, University of California, Los Angeles.

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R/CZ-141: 3.1.1998–2.29.2000

Determining the Processes that Control Kelp Spore Abundance

Paul Dayton

University of California, San Diego—Scripps Institution of Oceanography

California's towering canopies of giant kelp are the structure and substance for many of the state's most commercially valuable fisheries. Sea urchins, lobsters, crabs, rockfish, sea cucumbers and abalone all call the amber giant kelp forest home. As a source of alginates, texture-enhancing compounds put in ice cream, paint and medicines, kelp is itself a commercially important marine product.

Despite the kelp forest's biological and economic importance, kelp forest ecology is rich in unanswered, yet basic, scientific questions. What controls the abundance of kelp spores? Do spores from distant kelp beds re-seed local beds torn asunder by storms? Are many small kelp beds or fewer large ones better for maintaining healthy fisheries? All these are important questions for managing the state's marine resources and for preserving its remarkable natural history.

The Project

Kelp forest ecologist Dr. Paul Dayton of Scripps Institution of Oceanography and his graduate student Dr. Michael Graham, now a marine researcher at the University of California at Davis, were funded to study the reproductive processes of the Point Loma kelp forest in San Diego—one of the largest in the world, in bountiful years covering an area about 7 kilometers long and 1 kilometer wide.

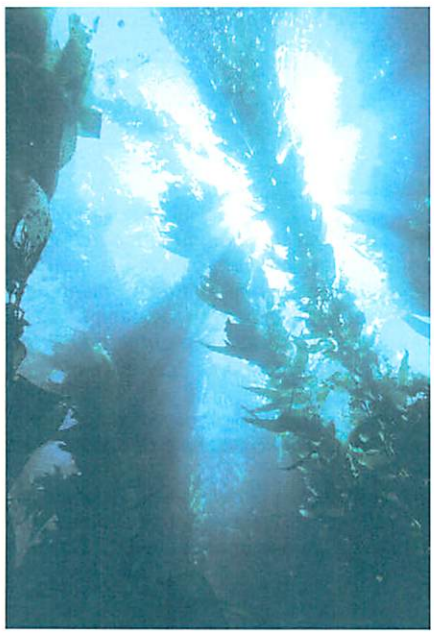
Giant kelp plants, which technically are not plants but algae, reproduce like ferns by dispersing spores. Spores are produced on special kelp blades on adult plants.

Previous studies have shown that large, dense kelp beds alter the flow of water through them. With the outer plants acting as a giant underwater wind block, the interior of a kelp bed may be almost motionless—even during a mild swell.

The main focus of this project was to investigate the degree to which spore abundance can be expressed as a function of location in the kelp bed, proximity to reproductively active plants and ocean current speed.

The Method

During the nine months between February and November 1999, the scientists collected water samples 26 times at 5 sites in the Point Loma kelp bed. On each dive, the scientists also took counts of all reproductively active plants, data that were used to estimate spore production at each site.



Mature kelp forest with large giant kelp (*Macrocystis pyrifera*) plants. In terms of supporting a diversity of life, giant kelp forests are to cold ocean environments what the coral reefs are to the tropics. Photo: Eric Hanauer.

Using a technique refined specifically for the project, water samples were analyzed for the abundance of a photosynthetic pigment unique to giant kelp plants. Ocean current speeds were based on historic current meter data.

The Findings

In the center of the kelp bed, the scientists found that spore abundance in the water column mirrored spore production from nearby adult plants. Based on their estimates, about 77 percent of the variability in spore abundance was associated with the rate of spore dispersal from nearby plants.

In contrast, near the edges of the kelp bed, spore abundance was not related to the rate of spore production. Instead, ocean currents, tides and winds were rapidly transporting spores great distances.

The spore analysis was consistent with physical oceanographic data showing that kelp forests alter ocean currents. In the center of the kelp forest, where ocean currents are weak, spores do not travel far. On the outskirts, where currents can be intense, spores are whisked away.

Implications

Dr. Graham said: "The work suggests that if you are interested in stabilizing a kelp forest, you have to take into account how big

the kelp forest is. A big forest is not the same as a little one. There is something special about a big forest in terms of its current flow and thus its ability to re-colonize itself.

"If individual kelp plants in the middle of a large kelp bed die, it is not a big deal because there will be plenty of spores to re-colonize the hole. For a smaller bed, the recovery process could be much more difficult since locally produced spores are transported elsewhere, with ocean currents.

"To protect a kelp forest, you don't want to focus entirely on the health of individual plants, but also on the density and size of the forest as a whole. It may not matter if there are healthy individuals. If you've changed the size and density of a bed, you've changed the currents and where the spores are going."

Publications

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Presentations

Graham, M.H. The secret life of kelps: Planktonic processes and population dynamics. Phycological Society of America Annual Meeting. San Diego, California, July 2000.

Graham, M.H. Spatio-temporal variability in the abundance of kelp planktonic stages. 5th Temperate Reef Symposium. Capetown, South Africa, January 2000.

Graham, M.H. Spatio-temporal variability in the abundance of kelp planktonic stages. Western Society of Naturalists Annual Meeting. Monterey, California, December 1999.

Graham, M.H. and B.G. Mitchell. Obtaining absorption spectra from individual macroalgal spores using microphotometry. 16th International Seaweed Symposium. Cebu City, Philippines, April 1998.

Trainee and Thesis

Graham, Michael H., Ph.D. in Biological Oceanography, Scripps Institution of Oceanography, University of California, San Diego 2000, "Role of Pre-Settlement Processes in the Population Dynamic of Subtidal Kelp."

Awards

Best Student Paper Award (Honorable Mention), Graham, M.H. Spatio-temporal variability in the abundance of kelp planktonic stages. Western Society of Naturalists Annual Meeting, Monterey, California, December 1999.

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R/CZ-157: 3.1.1998–6.30.1999

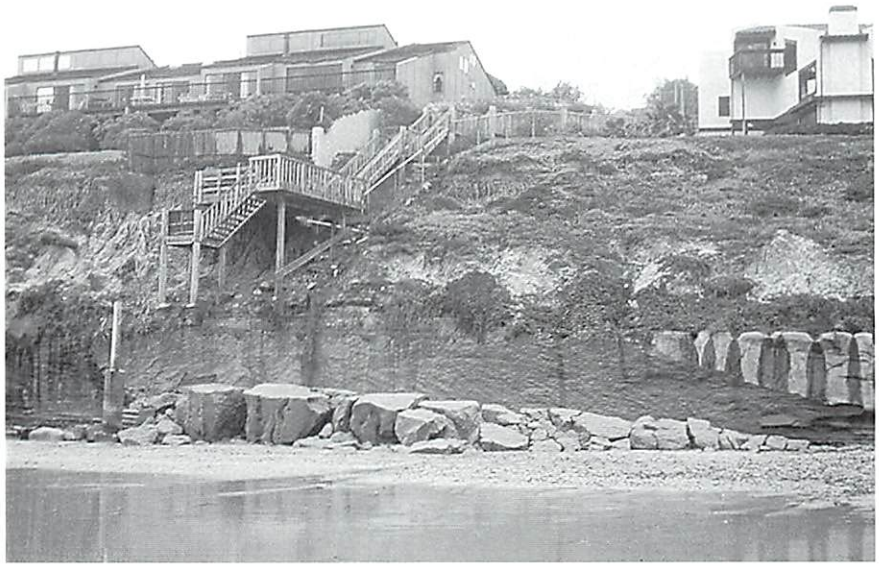
Coastal Cliff Erosion in San Diego County

Gary B. Griggs
University of California, Santa Cruz

Summary

Coastal erosion threatens to damage nearly 87,000 homes along the shoreline of the United States in the next 60 years, according to a report released in 2000 by the Federal Emergency Management Agency. Population growth, rising sea levels, hurricanes, dams (which block the resupply of sand to beaches) and severe storm events associated with El Niño events are escalating concerns that damage from shoreline erosion could cost hundreds of millions in coming decades. In California, these concerns are intensified by demographics and geography: about 80 percent of the state's 34 million residents live within 50 kilometers of the ocean and about 86 percent of the state's shoreline is classified as actively eroding.

Coastal bluff erosion is of particular concern in counties such as San Diego and Santa Cruz, where homes have been built on top of landslide-prone bluffs and where heavy surf scours the shore.



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

The Project

In this project, earth sciences professor Dr. Gary Griggs of the University of California at Santa Cruz was funded to investigate the influence of waves, groundwater and bluff composition on erosion rates in San Diego County. His work suggests that erosion estimates have overemphasized the role of wave action on bluff stability while underestimating the importance of bluff composition.

For the study, he and his colleagues analyzed historical aerial photos of the San Diego shoreline at eight representative sites, each nearly half a mile in length. The photos spanned a 40- to 60-year period, long enough to document changes in the position of the shoreline—the basis for calculating erosion rates.

They then examined the statistical relationships between erosion rates and those processes that cause seacliff failure. They looked, for example, at variations in wave energy along the coast, levels of groundwater seepage and at structural features of the sea cliffs, things such as joints and fractures.

Based on their analyses, the best predictor of bluff stability is bluff composition, particularly rock strength. Variations in rock material along the shore were associated with average rates of erosion that ranged from 3 centimeters a year in La Jolla to 43 centimeters a year in Carlsbad. Consistent with other studies, Dr. Griggs found that groundwater also plays an important role in weakening bluff materials.

Impacts

The technical underpinning of this study was the ability to use a process known as soft-copy photogrammetry to digitize aerial photos of the coast without significant distortion and at high resolution. Without these high-resolution digital images, it would have been impossible to compute erosion rates. Dr. Scott Ashford of University of California, San Diego has been funded by California Sea Grant to use photogrammetry to evaluate the effectiveness of bluff-stabilization methods in San Diego County.

The 2000 FEMA report on coastal erosion included Griggs' analyses for San Diego and Santa Cruz counties.

Cooperating Organizations
United States Geological Survey
Westerm Coastal and Marine Geology Team

Publications

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Benumof, B.T., and G.B. Griggs. 1999. The dependence of seacliff erosion rates on cliff material properties and physical processes: San Diego County, California. *Shore & Beach* 67(4): 29–41.

Trainee and Thesis

Benumof, Benjamin T., Ph.D., University of California, Santa Cruz, 1999, "The Dynamics, Kinematics and Geomorphic Evolution of the San Diego Coastline."

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Sea Grant California

COASTAL OCEAN RESEARCH

R/CZ-146: 3.1.1998–2.29.2000

A Better Method for Evaluating Heavy Metal Water Pollution

Janet Hering
California Institute of Technology

Background

High concentrations of heavy metals, and even trace amounts of some, can be harmful to both plants and animals. The toxicity of heavy metal contamination, however, is highly dependent on the chemical form of the metal in question. For instance, in general, metals that are bound in particles or to organic (carbon-containing) compounds are less toxic than dissolved free ions, less toxic meaning that the metals are less readily available for uptake by marine organisms.

Traditionally, efforts to control heavy metal pollution have focused on monitoring the "total recoverable" or "total dissolved" fraction of a metal in seawater samples. In quantifying these fractions, water samples are mixed with a strong acid. The sample is vaporized and ionized, and typically a beam of light is then passed through the sample. The amount of light absorbed by the sample gives an estimate of the amount of the metal. Although this method, called atomic absorption spectroscopy, is relatively straightforward and inexpensive, it does not discriminate among different chemical forms of metal-containing compounds, and thus it does not directly evaluate the toxicity of contamination. This means that it rarely provides a good prediction of the human or environmental health risks associated with contamination.

The Project

In this project, Dr. Janet Hering, an environmental engineering professor at the California Institute of Technology, was funded to begin to develop the tools that one day will make it possible to measure the bioavailable fraction of metal pollution in seawater. For the project, Dr. Hering used chromatography coupled with mass spectrometry to separate and quantify organic complexes of copper and nickel in idealized, laboratory conditions.

In this method, the sample is injected into a plasma, where it is vaporized and ionized. Metal ions are then sent to a mass spectrometer which sorts the ions according to their atomic mass. Those ions with an atomic mass corresponding to the metal compound in question are then measured.

Underscoring the challenges of evaluating the bioactive component of heavy metal pollution, Dr. Hering found that her method is not yet sensitive enough to measure metal compounds in water samples collected from coastal waterways.

She cited the rapidity with which metals are exchanged among organic compounds as being one factor that makes measuring heavy metal pollution a moving target.

Applications

Progress in developing instruments that can speciate different

It takes very complex instrumentation to measure the different metal-containing compounds in water. Here is an instrument used by Dr. Janet Hering of the California Institute of Technology to measure copper and nickel in laboratory water samples. Photo: California Institute of Technology.

metal-containing compounds is a first step toward being able to determine the bioavailable fraction of metal contamination. From a policy-making standpoint, these tools are what are needed to refine existing regulations.

The ability to measure the bioavailable fraction of heavy metal contamination would also help communities evaluate their water quality (in marinas and harbors, for instance, where antifouling hull paints contribute to copper pollution), identify sources of contamination and prioritize cleanup efforts based on their relative toxicity to the environment.

Publications

Piatina, T.B., and J.G. Hering. 2000. Direct quantification of metal-organic interactions by size-exclusion chromatography (SEC) and inductively coupled plasma mass spectrometry (ICP-MS). *J. Environ. Qual.* 29:1839–1845.

Trainee and Thesis

Piatina, Tatiana, Ph.D, California Institute of Technology, June 2001, "Studies of Metal-Organic Interactions with Model Synthetic and Natural Ligands Applicable to Natural Waters."

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R/C-46PD: 3.1.1999–9.30.2000

Detection of Human Viruses in Coastal Waters of Southern California

Sunny Jiang
University of California, Irvine

Summary

Using a technique developed to track pathogens in sewage, Dr. Sunny Jiang of the University of California at Irvine has shown that human viruses, not just fecal bacteria, are contaminating a significant percentage of river mouths in Southern California.

Her test does not tell whether the viruses are virulent, but their presence does indicate that human waste is making its way into urban waterways. Because of the health risks associated with human waste, some groups are beginning to test creeks and drainage culverts for signs of human viral contamination.

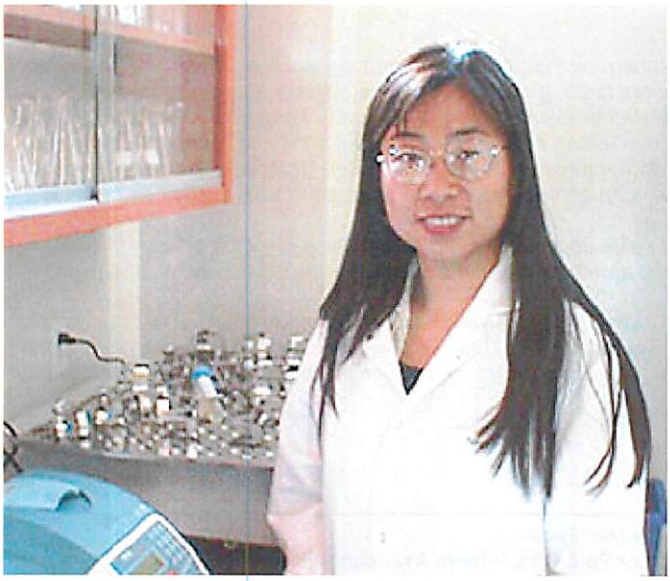
Coastal pollution is nothing new to Southern California. Many coastal waterways in Southern California fail to meet water-quality standards set by the federal Clean Water Act, and California has more beach closures than any other state. However, none of these standards are based on viral contamination. Dr. Jiang's work draws attention to the limitations of current water-testing standards.

The Project

In her study, Dr. Jiang analyzed water samples collected at 12 major river mouths in San Diego, Orange and Los Angeles counties for the presence of the human adenovirus—a cousin of the hepatitis A virus found in the human intestinal track.

The adenovirus, one of dozens of pathogenic viruses found in human feces, was tracked because of its unusual genetic signature. Unlike many human viruses, which contain fragments of RNA, the adenovirus is made of pieces of DNA.

Based on her analysis, four of the 12 sites tested positive for the presence of the adenovirus: the Los Angeles, San Gabriel, Santa Ana and Tijuana river mouths. Of these four, only the Los Angeles river mouth also registered as having high fecal bacteria levels—the standard criteria for evaluating water quality, closing beaches and monitoring compliance with federal clean water laws.



Dr. Sunny Jiang, a water quality expert at the University of California, Irvine, is developing tools for measuring viruses in coastal waters. To detect viruses, she must collect 20-liter water samples.
Photo: University of California, Irvine.

Implications

Dr. Jiang's work raises questions about whether current water-quality standards adequately protect human health. Some of her experiments, for example, have shown that indicator bacteria counts can be normal even when waters are contaminated with human viral pathogens.

"Our current bacterial indicators may not reflect the safety of water," she said. "When the presence of the virus is uncorrelated with high bacterial levels, beaches are not closed, and people are potentially exposed to health risks."

Collaborations

Dr. Jiang has worked with the Public Facilities and Resources Department in Orange County to test chronically polluted waters in the Aliso Creek watershed. She is also working with other University of California researchers on a project to study the impact of the Santa Ana River on beach pollution in Huntington Beach in Orange County. Their work may lead to an explanation of what caused a spate of beach closures in Huntington Beach in 1999 and 2000.

She currently has funding from the Water Environment Research Foundation to develop a rapid, more automated technique for monitoring human viruses in seawater samples. The new instrument will be able to count viral loads—an improvement over the current method, which only detects the absence or presence of the human adenovirus.

Cooperating Organizations

Southern California Coastal Water Research Project

Publications

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Technical Report

Southern California Bight 1998 Regional Monitoring Program: Winter Shoreline Microbiology. Prepared by Southern California Coastal Water Research Project.

Trainee

Becker, Sarah, graduate studies in Environmental Analysis and Design, University of California, Irvine.

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R/CZ-145: 3.1.1998–2.29.2000

Understanding Domoic Acid and Toxic Diatom Blooms

Mary Silver
University of California, Santa Cruz

Background

In general seafood is safe, tasty and nutritious, but there are some naturally occurring toxins that can make seafood dangerous for consumers. One such toxin is domoic acid, a potent neurotoxin produced by microscopic diatoms of the genus *Pseudo-nitzschia*.

Diatoms are single-celled, photosynthetic organisms, and as the sea's primary fixers of carbon, form the base of the marine food chain. Although fish and shellfish that consume diatoms accumulate domoic acid without apparent harm, people who ingest contaminated seafood can suffer permanent brain damage, characterized by permanent memory loss, a condition known as amnesic shellfish poisoning. Domoic acid poisoning may also cause seizures, coma and, in rare cases, death. In mild cases, symptoms are indistinguishable from those of generic food poisoning.

As researchers work to understand what triggers domoic acid production in diatoms, two pieces of information are worth considering. Sediment cores suggest that *Pseudo-nitzschia* diatoms have lived off the California coast for the last 1,000 years. Yet, the first documented case of domoic acid poisoning on the West Coast occurred relatively recently, in 1991, after an analysis of a series of strange bird die-offs in California tied the deaths to contaminated anchovies.

The Project

Dr. Mary Silver, a professor in the Department of Ocean Sciences at the University of California at Santa Cruz, was funded to trace domoic acid through the marine food web. Her project was prompted by a 1998 die-off of sea lions in Central California.

The project began with researchers collecting anchovy specimens from California fishing boats. Sea Grant Trainee Dr. Kathi Lefebvre, now a researcher at the NOAA laboratory in Seattle, then showed that the anchovies were contaminated with domoic acid. Sea lion feces were also found to be high in domoic acid. Necropsies of sea lions revealed that the animals' stomachs were full of tiny skeletons of *Pseudo-nitzschia* diatoms. The analysis left little doubt that anchovies that had eaten contaminated diatoms had in turn poisoned sea lions. This was a significant finding because it established the toxicity of domoic acid in large marine mammal predators.

Dr. Mary Silver, Professor of Ocean Sciences, University of California, Santa Cruz.

In a separate study, the scientists tried to identify environmental factors that might promote domoic acid production. Specifically, they looked at the role of natural levels of nitrate and silicate on domoic acid production.

It is not known why diatoms

Although domoic acid is harmless to fish, it can be deadly to pelicans and marine mammals that ingest contaminated fish. The first documented domoic acid outbreak in California occurred in 1991 and caused a rash of pelican and cormorant deaths. A second outbreak in 1998 was fatal to sea lions. In 2002, dophins fell prey to the toxin for the first time. Photo: California Sea Grant.

produce domoic acid, but one theory is that domoic acid may help diatoms absorb iron, when nutrient levels are unusually low.

Consistent with the theory that domoic acid production is not enhanced by nutrient pollution, they found that domoic acid production was highest when nutrient levels were lowest. That is, nutrients in fertilizer do not appear to contribute to domoic acid production.

"It is not at all clear that there is any connection between human activity and toxin production, in this particular case," Dr. Silver said. "There may or may not be any human connection. The reservoirs of iron in the sea, so far, seem to have relatively little to do with human activity."

Applications

The data collected during this project were shared with the California Department of Health Services. In response to the information, the agency closed the anchovy fishery until domoic acid levels returned to safe levels.

Although fishery closures are undesirable for fishing communities, they benefit fishers in the long run by maintaining the safety and reputation of California's seafood products.

Anchovies are not only eaten by people but are also ground into fish meal for poultry and pig feed. Without the information gathered during this project, domoic acid poisoning might have killed people and contaminated aquaculture and meat products.

Domoic acid has recently been identified as a problem in the viscera of Dungeness crab, tanner crab, red rock crab, and anchovies along the West Coast.

Publications

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Trainees and Theses

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Lefebvre, Kathi A., Ph.D. in Biology, University of California, Santa Cruz, May 2001, "Effects of Domoic Acid on Northern Anchovies and Their Role as a Vector of the Neurotoxin to Higher Trophic Levels."

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Sea Grant California

COASTAL OCEAN RESEARCH

R/CZ-144: 3.1.1998–2.29.2000

Domoic Acid in Marine Diatoms: Biochemical Pathways and Environmental Regulation

G. Jason Smith

San Jose State University—Moss Landing Marine Laboratories

Background

The coastal United States has more toxic algal species, more algal toxins and more toxic algal blooms than ever before. The apparent spread of harmful agal blooms not only poses a human health threat but also has significant economic consequences for the seafood industry.

While declining water quality may be one reason for many of the observed increases in toxic blooms, the mechanisms through which man-made pollutants contribute to algal blooms is not well understood. Some of the "new" harmful algal blooms, for instance, have occurred in relatively pristine waters off the coast of Alaska and may be an artifact of better environmental testing. In the case of domoic acid, one of the more recently discovered toxins on the West Coast, sediment cores suggest the diatoms that synthesize the toxin have lived in coastal waters for more than a thousand years and are ubiquitous in coastal waters.

The Project

The purpose of this project was to identify environmental cues that can trigger toxic *Pseudo-nitzschia* blooms by examining the biochemical pathways of domoic acid (DA) production in these diatoms. Diatoms within the genus *Pseudo-nitzschia* produce DA.

More specifically, the focus of the study, led by Dr. G. Jason Smith of Moss Landing Marine Laboratory, was to investigate the hypothesis that DA is produced in *Pseudo-nitzschia* in response to stress. This hypothesis is motivated, in part, by the striking structural similarity between domoic acid and proline, an amino acid produced by many marine organisms in response to stress.

The Method

To examine the effects of environmental stress on diatoms, Dr. Smith exposed diatoms to varying levels of copper, urea, nitrate and silicate. Copper is an essential nutrient that becomes toxic at high levels. Nitrate and urea both contain nitrogen, which is required for reproduction and cell growth. For this reason, plankton blooms cannot occur without a minimal amount of nitrogen. Silicate is another essential nutrient, used by diatoms to construct their frustules, or shells.

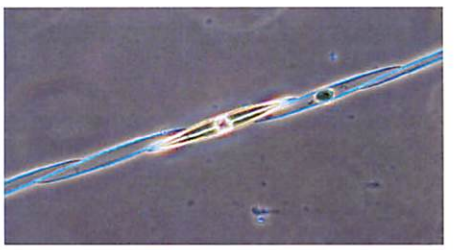
After exposing diatoms to nutrients, Dr. Smith measured levels of three key amino acids—DA, proline, and taurine. Taurine may reduce the toxicity of DA.

The Findings

The findings from this project support the theory that stress can trigger DA production.

Dr. Jason Smith found that:

Photomicrograph of a dense bloom of diatoms from Monterey Bay, September 2000. The dominant needle-like cell chains are *Pseudo-nitzschia australis*. Photo: G. Jason Smith ©2000.



Photomicrograph of the toxic diatom *Pseudo-nitzschia australis*, isolated from a net tow during a bloom in Monterey Bay in September 2000. Note: the middle cell is alive while the two flanking cells are in states of senescence. Photo: G. Jason Smith ©2000.

- as silicate levels were lowered, DA production increased as much as a hundredfold;
- cells producing high levels of DA had relatively low levels of proline and relatively high levels of taurine; and,
- DA levels were higher when copper concentrations were higher and lower when copper levels were lower.

He also observed that nitrogen in urea and nitrate had no effect on DA production, beyond its known role in regulating cell growth.

Dr. Smith recently received funding from the National Science Foundation to isolate genetic markers that can be used to monitor DA production in diatoms from Monterey Bay.

Applications

This project helps answer basic genetic and biochemical questions about how and why cells produce DA. This information potentially can be used to help develop treatments for shellfish poisoning, and it has direct relevance for improving monitoring of coastal waters. At present, the state tests waters for the presence of *Pseudo-nitzschia*

diatoms but does not have the ability to tell whether these diatoms are actively producing DA. Dr. Smith said that his work lays the foundation for genetic fingerprinting that can discriminate between DA-producing and non-producing diatoms.

Cooperating Organizations

Merck & Company, Inc.
Monterey Bay Aquarium Research Institute
Provasoli Guilliard National Center for the Culture of Marine Phytoplankton
University of California, Santa Cruz—Marine Sciences Institute

Presentations

Ladizinsky, N.L., G.J. Smith, and K.H. Coale, 2000. Intracellular accumulation of domoic acid by *Pseudo-nitzschia* multiseries in response to increasing total copper levels. Sanctuary Currents 2000. Monterey Bay National Marine Sanctuary Symposium: Causes of Ecosystem Change: Natural or Human?, Santa Cruz, California.

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Smith, G.J. 1999. HAB or HAB NOT Workshop: Evaluation of the relationship between domoic acid and proline metabolism in *Pseudo-nitzschia* spp. from Monterey Bay, California. Invited instructor for an online, interactive presentation sponsored by the College of CoExploration and USC Sea Grant. Conference website: http://www.coexploration.org/hab. Presentation website: http://members.aol.com/symbios222GJSHAB99.html.

Awards

The Fred and Ethel Meyers Marine Biology Trust Award
Sigma Xi Grant in Aid of Research

Graduate Trainee and Thesis

Ladizinsky, Nicolas L., M.S. in Chemical Oceanography, California State University, Monterey Bay, anticipated June, 2002, "Accumulation of Domoic Acid by Diatoms in the genus *Pseudo-nitzschia* in Response to Increasing Cupric Ion Activity: A Possible Complexation Strategy."

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R/CZ-170: 3.1.2001–2.29.2004

Monitoring the Fluxes of Salinity, Pollution and Phytoplankton into the San Francisco Bay

Mark Stacey
University of California, Berkeley

Background

Estuaries are transition zones separating freshwater and saltwater ecosystems. They provide both a physical barrier protecting the shoreline from the direct force of storms, and they create unique habitats for fishes and birds.

Estuaries are distinguished by their relatively large swings in salinity. While the tides rhythmically flood estuaries with saltwater, elevating salinity levels, rivers supply freshwater, lowering them. Without tidal flows, estuaries may lose their ability to support marine species, and they may accumulate pollutants. Alternatively, without freshwater, seawater may intrude far upstream, contaminating aquifers and killing wildlife.

A proper balance of tidal flushing and clean freshwater inputs is crucial to maintaining the biological health of estuarine ecosystems. For these reasons, and others, it is important to understand how salinity levels vary with tidal cycles, winds, and ocean currents.

About 80 percent of all freshwater entering the San Francisco Bay comes from the Sacramento River (pictured above). Nearly all this water is released from reservoirs fed by the Sierra Mountains. The reservoirs supply the state with water for agriculture and urban use. Photo: Dale Kolke, California Department of Water Resources.

An aerial view of the Sacramento–San Joaquin Delta. When and how much water is released into the delta is a management decision, based largely on estimates of how river flows will influence salinity levels and how these changes in salinity, in turn, will affect wildlife. Photo: Dale Kolke, California Department of Water Resources.

The Project

The main goal of this project is to study the fluxes of salt, temperature, suspended solids and phytoplankton between the San Francisco Bay and the coastal ocean. To do this, scientists will measure current speeds along a transect across the mouth of the bay, a length of about 5 kilometers. Salinity, temperature, turbidity and phytoplankton abundance will simultaneously be measured along the same transect. Ultimately, scientists would like to identify whether tides, winds, rivers or gradients in water density drive

fluxes of salt, pollution and phytoplankton into the bay.

Method

Salinity, temperature, turbidity and chlorophyll concentrations will be directly measured from water samples collected during six cruises. Measurements will be taken across the mouth of the estuary continuously over a 25-hour period in which time two full tidal cycles can be observed. Ocean currents will be measured with an acoustic current Doppler profiler—an instrument that uses backscattering and frequency shifts of sound waves to estimate current speeds.

Applications

The findings from this project will lead to a better understanding of how physical processes influence biological processes, such as phytoplankton productivity, in the estuary. Beyond the biological implications, which have attracted the attention of scientists from the Romberg Tiburon Center, the Interagency Ecological Program, and the U.S. Geological Survey, the findings from this project will have important implications for determining the net transport of sediment and contaminants between the San Francisco Bay and the ocean. Net transport rates are also of interest to the Port of Oakland and the San Francisco Airport Authority.

In addition, this project gives insights into the effects of water diversions on the Bay–Delta system, underscoring the delicate balance between tidal flows and freshwater inputs.

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R/CZ-171: 3.1.2001–2.28.2004

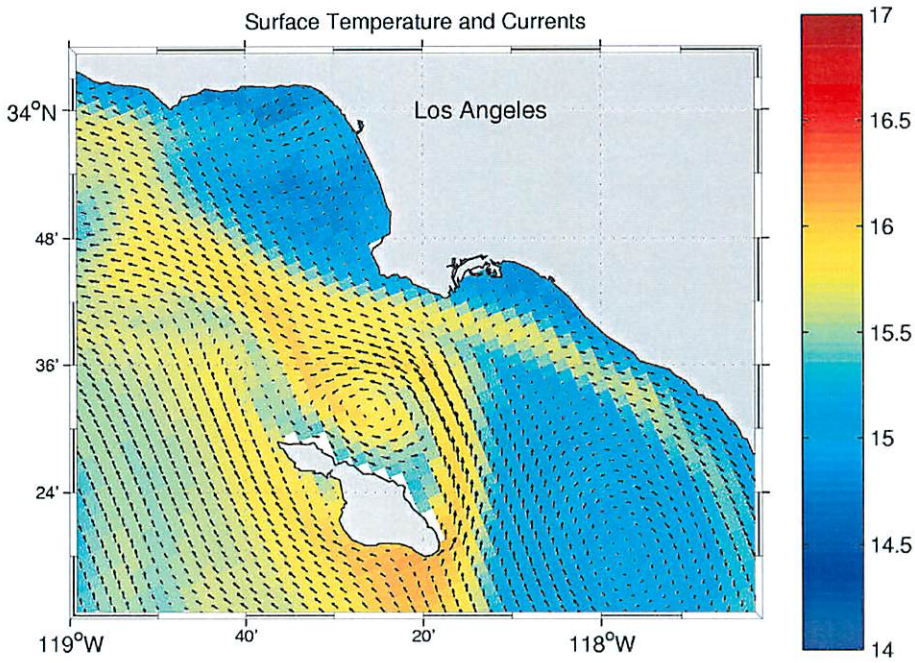
Modeling Water and Sediment Quality in Two California Bays

Keith Stolzenbach and James McWilliams
University of California, Los Angeles

Background

Highly urbanized bays, especially shallow, protected ones are extremely prone to water pollution. Not only do these waterways receive pollutants from sewage, storm drains, rivers and industrial discharges, but the pollutants are slow to disperse—and slow to be diluted with water from the open ocean.

While polluted coastal bays have often been studied observationally, less effort has focused on developing computer models that simulate the processes that disperse, deposit and re-suspend pollution and contaminants on the seabed. Such models would not only help interpret observational data but would also benefit resource managers charged with upholding state and federal clean water laws.



Horizontal water velocities in the Southern California Bight at 50-meters depth (the maximum vector length is 0.23 m/s) estimated using a three-level grid configuration. Velocities are plotted on a contour map of wintertime sea surface temperatures (see color bar, in degrees Celsius). Credit: Marchesiello P., J.C. McWilliams, J. Oram and K. Stolzenbach. 2002. Equilibrium circulation in the Southern California Bight, in preparation.

The Project

In this project, Drs. Keith Stolzenbach and James McWilliams, both of the University of California at Los Angeles, are developing a 3D computer model that simulates the distribution of temperature, salinity, nitrogen and phytoplankton in coastal bays. The model also simulates the biogeochemical processes involved with the dispersion (suspension, sinking and aggregation) of particulate matter.

The model that they will be developing is a modified version of an Ocean Modeling System developed in an earlier California Sea Grant project. Whereas the first model simulated oceanic processes along the entire West Coast (from Alaska to Baja California) and resolved features on a scale of 10 kilometers, the new Regional Ocean Modeling System is being programmed to resolve oceanic processes on a 1-kilometer scale. What further distinguishes the new model is its ability to simultaneously resolve large-scale and fine-scale oceanic processes and to consistently simulate the interactions between the two scales. All this is being done by "embedding" the regional, 1-kilometer calculations within the more global calculations on the 10-kilometer grid.

The strength of such a calculation is that it takes into account how large-scale processes—winds and variations in the California Current—"force" less noticeable, smaller currents that may, for instance, sweep raw sewage onto a favorite beach. Typically, computer models that resolve oceanic processes on a scale fine enough to study coastal bays and beach processes ignore the contribution of large-scale processes.

One major goal of the project is to produce a series of simulations that represent common oceanographic phenomena for two case-studies—the Santa Monica and Monterey bays. These scenarios include understanding:

- the circulation patterns that disperse runoff after a heavy winter rainstorm;
- the dispersion and fate of heavy

metals; and,
• the origin and evolution of toxic plankton blooms.

Applications

The scientists plan to incorporate data on sewage discharges into the model to track the predicted paths of contaminants along the coast. Another scenario the scientists hope to model is the dispersal of fish larvae by ocean currents and winds.

To validate the model's accuracy, the scientists will compare model simulations with observational data collected at sea and by satellites.

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PUB. NO. CSG-CZ-02-012 **JANUARY 2002**

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R/CZ-142: 3.1.1998–2.28.2001

Sublethal Toxic Effects of Water Pollution on Red Abalone

Ronald Tjeerdema
University of California, Davis

Summary

Though difficult to quantify, chemicals in agricultural and urban runoff are contributing to population declines of commercially valuable marine species. Although these pollutants may not be immediately lethal to marine organisms, they can impair key biological processes, hindering reproduction and causing early death.

Using technologies developed for the medical profession, Dr. Ron Tjeerdema of the University of California at Davis has been able to show that low levels of chemical pollutants impair red abalones' metabolic processes. Although not immediately lethal, a significant loss of muscle function can eventually be fatal.

His findings suggest that current water-testing methods, because they focus on identifying the point at which pollutants are lethal to target marine species, may be inadequately protecting marine life, particularly invertebrates and marine larvae. His findings support a growing interest in developing techniques that make it possible to evaluate nonlethal effects of runoff along the coast.

Abalones were once one of California's most lucrative fisheries before overfishing and disease forced the California Department of Fish and Game to place a moratorium on all commercial abalone diving.

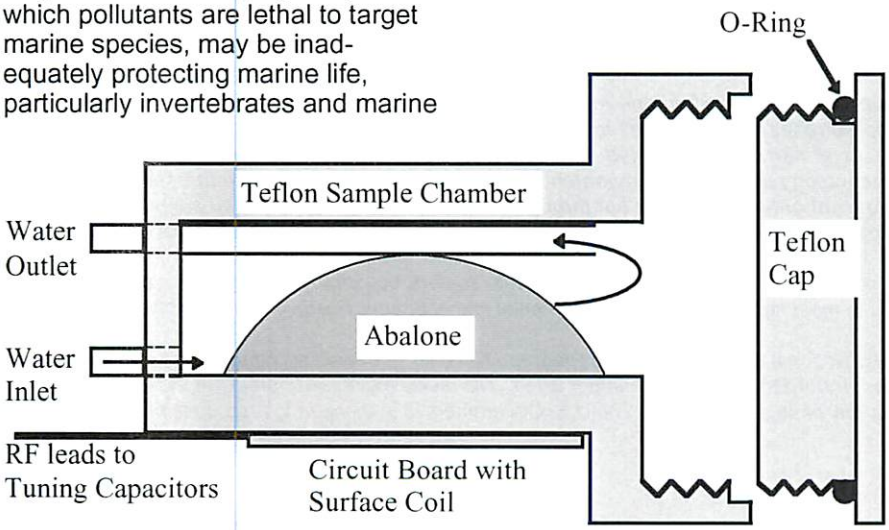
Goals

The overall goal of this project was to show the feasibility of measuring the chronic effects of low-levels of chemical pollution on marine life. For this project, Dr. Tjeerdema demonstrated that it is possible to use nuclear magnetic resonance (NMR) spectroscopy (a technique commonly used to visualize sports injuries) to characterize the cellular response of red abalone to high concentrations of wood preservative and copper. He then tracked the cellular damage caused by lower concentrations of these same toxins.

Dr. Ron Tjeerdema.
Photo: UC Davis.

The magnetic imaging showed that nonlethal exposure to toxins reduced adenosine triphosphate (ATP) production in the abalone's foot muscle. ATP, a molecule found in all living organisms, is the primary source of usable energy for cells. As ATP production declines, muscle function is lost.

Dr. Tjeerdema then tested the possibility of using the common owl limpet as a biological indicator of chemical pollution. Unlike abalone, owl limpets are still abundant in the subtidal rocky habitat in both Northern and Southern California. He was able to calibrate decreasing rates of ATP production in limpets with increasing levels of chemical contamination.



Most instruments for measuring the nonlethal effects of water pollution have been designed for air-breathing subjects. The diagram above shows how Dr. Ron Tjeerdema modified a nuclear magnetic resonance probe to image the effects of copper pollution on abalone. Illustration: Ron Tjeerdema.

Implications

This project represents an important step toward documenting the effects of chronic pollution on marine organisms. The project's findings can be used "to establish scientifically sound criteria for

stricter, more protective, water-quality standards," Dr. Tjeerdema said. The California Department of Fish and Game, the State Water Resources Control Board and the Department of Health Services have expressed interest in using the NMR technique to characterize the nonlethal effects of toxins on aquatic animals.

Some of Dr. Tjeerdema's other research projects have resulted in new regulations on pesticide runoff from agriculture.

Cooperating Organizations

The California Department of Fish and Game

Publications

Martello, L.B., and R.S. Tjeerdema. 2001. Combined effects of pentachlorophenol and salinity stress on chemiluminescence activity in two species of abalone. *Aquat. Toxicol.* 51:351–362.

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Graduate Trainees and Theses

Martello, Linda, Ph.D. in Biology, University of California, Santa Cruz, Sept. 1999. "The Combined Effects of Chemical and Natural Stressors on Phosphagens and Nonspecific Immunity in Two Species of Abalone."

TenBrook, Patti, Ph.D. in Agricultural and Environmental Chemistry, University of California, Davis, anticipated 2004.

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R/CZ-175: 3.1.2001–2.28.2003

Fate and Transport of Planar and Mono-Ortho Polychlorinated Biphenyls and Polychlorinated Napthalenes in Southern California Sediments

M. Indira Venkatesan

University of California, Los Angeles—Institute of Geophysics and Planetary Physics

Background

Treated sewage, storm water runoff and industrial waste are sources of chemical contamination in coastal sediments. Although studies of sedimentary chemistry have resulted in stringent laws on discharging toxic chemicals into the sea, the more toxic chemicals can have lasting effects on the environment.

Polychlorinated biphenyls (PCBs) are one example of a group of chemicals that were banned because of their extreme toxicity to wildlife, but nonetheless remain a long-term problem for human health and marine life. The Environmental Protection Agency, for example, estimates that 10 tons of PCBs remain in ocean sediments on the Palos Verdes shelf. PCB and DDT contamination have resulted in commercial fishing bans and recreational catch limits for white croaker in the area.

The most toxic of all PCB compounds are the "co-planar" or "non-ortho" PCB congeners. There are 209 congeners of the PCB molecule, representing the set of all possible arrangements of chlorine atoms in the molecule's biphenyl ring. All 209 congeners are toxic, but the most toxic and least abundant are the co-planar ones.

The Project

The goal of this project is to investigate the distribution and fate of the different PCB congeners in sediments in the Southern California Bight. This will be the first study that attempts to isolate and analyze the co-planar component of PCB contamination on the West Coast.

For the project, Dr. M. Indira Venkatesan, a geochemist at the University of California at Los Angeles, plans to analyze 8 sediment cores from San Pedro and Santa Monica basins, each of which records nearly a century of deposition. She will also analyze a large number of surface sediment samples collected in the Santa Monica Bay between 1997 and 2001.

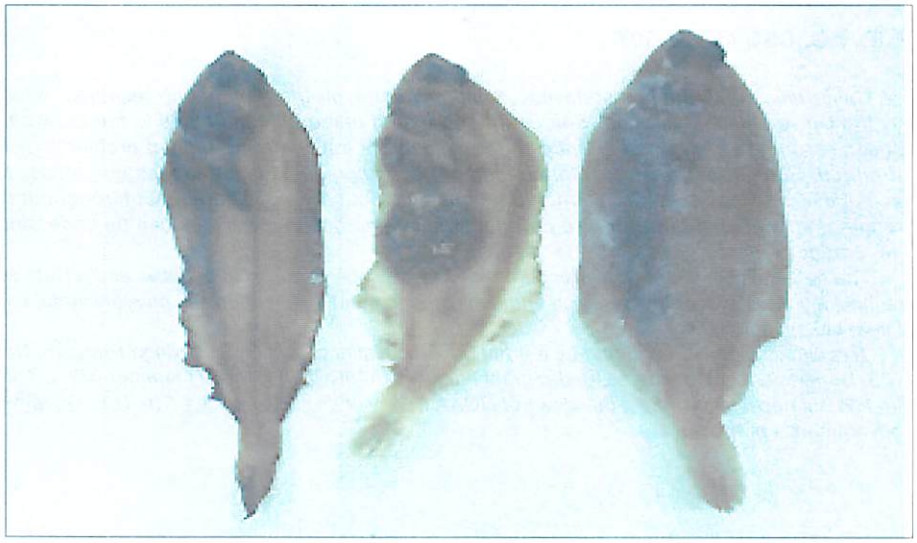
Despite the widespread belief that PCBs are not biodegradable and relatively stable, recent studies suggest that microbial processes may remove chlorine atoms from the highly chlorinated, non-ortho PCBs. Microbes thus seem to selectively remove chlorine atoms from the most toxic, co-planar, congeners. Dr. Venkatesan said that if this process works, it "should result in the detoxification and subsequent microbial degradation of PCBs with lower chlorine numbers."

Dr. Venkatesan's work will examine whether microbial processes do detoxify PCB congeners in marine sediments. Other objectives include:

- mapping the spatial and temporal distribution of sediment contamination in the Bight;
- mapping the distribution of polychlorinated naphthalenes (PCNs) in the Bight. PCNs are toxic industrial compounds that, in general, seem to be associated with PCB contamination; and,
- understanding the dispersal of PCBs and PCNs in the coastal zone.

Applications

The data gathered for this project can serve as a scientific basis for reconstructing a historical record of sediment contamination in the state. Such a record can be incorporated



Dover sole collected in the 1970s from coastal waters off Palos Verde in Los Angeles show the damaging effects of contaminants and parasites. The specimen on the far left suffers from severe fin erosion caused by pollutants such as DDT and PCB, the one in the middle has large tumors from parasites. The sole on the right is normal. Because of strict laws, diseased fish such as these are today rare. Photo: Southern California Coastal Water Research Project.

into the state's Ocean Plan, which calls for establishing sediment quality objectives. The State Water Resources Control Board adopted the first Ocean Plan in 1972 to set water quality objectives for the state's ocean waters and to coordinate efforts to meet federal environmental laws.

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Sea Grant California

COASTAL OCEAN RESEARCH

R/CZ-136: 3.1.1997–6.30.1999

Predicting Flows in Semi-Arid Watersheds Using GIS Technologies

Richard Wright
San Diego State University

Background

The Tijuana River Watershed drains 1,750 square miles of highly varied habitat straddling both sides of the U.S.-Mexico border. The complex network of seasonal creeks that feed this watershed is prone to destructive flash flooding and is known to contribute significantly to chronic beach pollution. As the populations of Tijuana and San Diego continue to grow, it is expected that water quality will continue to decline and flood damage increase unless action is taken.

Although streams are usually either unmonitored or inadequately monitored, reliable estimates of stream flows are needed for developing flood-warning systems and for cost-effectively addressing ways to reduce ocean pollution.

The Project

The goal of this project was to use geographic information system (GIS) technologies to develop a simple stream-discharge model for predicting flows through the Tijuana River Watershed. The project is linked to an ongoing project to create a GIS-database for the San Diego–Tijuana area, funded by the National Oceanographic and Atmospheric Administration, the Environmental Protection Agency, and the Southwest Center for Environmental Research and Policy.

The first phase of the Sea Grant project involved integrating all the different data sets needed to accurately model river flows—data on elevation, precipitation, temperature, soil type, soil porosity and vegetation, combined with information on the locations of roads, sewers and utility lines.

Because most hydrologic models have been designed for temperate climates, Dr. Wright and colleagues developed a Physical Hydrology Simulator for modeling monthly river flows in the semiarid, chaparral-dominated coastal watersheds of California.

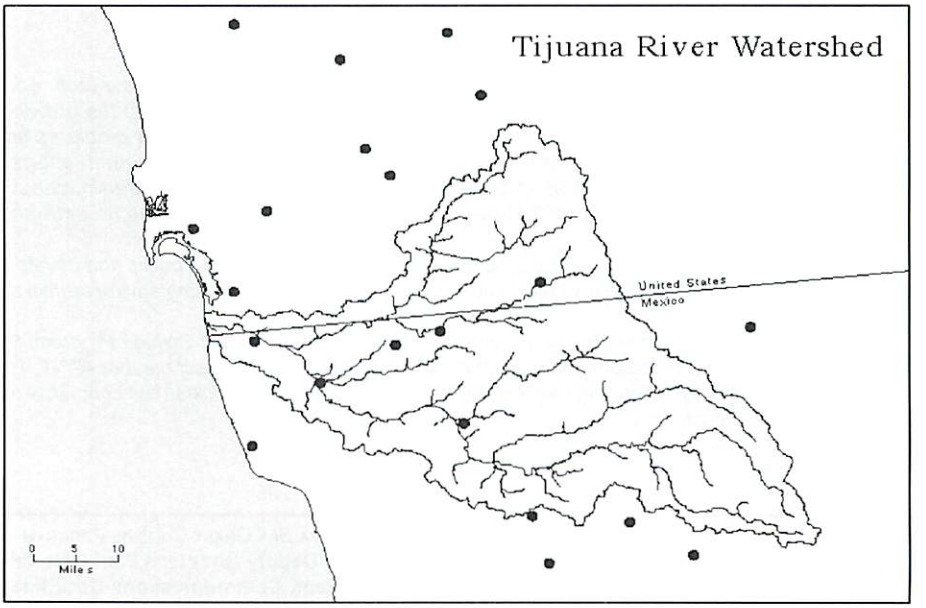
To test and fine tune the Hydrology Simulator, they compared predicted monthly river flows to real data for the Campo Creek watershed, a subbasin of the Tijuana River Watershed.

The scientists found that calibrating their models was difficult because of the complex nature of hydrologic processes in semiarid watersheds and because of an absence of high-quality data on stream flows and rainfall. Uncertainties in the model were greatest for low flows.

Researchers at the Department of Geography at San Diego State University are now evaluating the predictive capability of more complex river flow models in semiarid watersheds of California.

Applications

The model developed for this project, in conjunction with comprehensive rain gauge and stream-flow data, will enable scientists to calculate the magnitude of 25-, 50- and 100-year floods. From this, it will be possible to develop a binational flood-warning system for the entire watershed. Dr. Wright is currently working with the County of San Diego, the City of Tijuana, and the National Weather Service to develop a flood-warning system for the Cottonwood Creek–Rio Alamar portion of the Tijuana River drainage area. Flood waters along the Rio Alamar not only cause loss of life and property but contribute to coastal water pollution and burden



The above map shows the locations of rain gauges of relevance to this study.
Credit: Richard Wright, San Diego State University.

the Tijuana Estuary with sediments and contaminants from streets, lawns and storm drains.

Cooperating Organizations

City of San Diego Water Utilities Department
International Boundary and Water Commission
San Diego Association of Governments
San Diego County Department of Public Works
United States Geological Survey

Presentations

Five papers and four posters were presented at professional scientific conferences.

Awards

California Geographic Information Association Award for Outstanding Contributions to Geographic Education and Partnerships
Phi Kappa Phi National Honor Society, 1998

Trainees and Theses

Two doctoral students and seven master's students, all in the geography department at San Diego State University, received support through this grant.

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R/CZ-152: 3.1.1998–9.30.2001

Finding the Chemical Signals that Induce Marine Larvae to Settle to the Sea Floor

Richard Zimmer
University of California, Los Angeles

Background

Many benthic marine animals begin life as free-floating larvae, drifting high above the ocean floor. A number of these, after feeding on algae, descend to the ocean bottom, where they complete their metamorphoses into miniature versions of their adult forms. These barnacles, clams, oysters and starfishes will spend the rest of their lives on the seafloor, never again being as mobile as they were as larvae. For this reason, perhaps the most important event of their lives is settling onto prime rock substrate.

Up until recently, the common wisdom among scientists was that larvae are passive drifters, tossed at the whim of powerful waves and currents. Where they settled was believed to be a matter of random chance. This theory had holes, however, since field observations consistently showed that settlement rates are higher on preferred reef materials.

In this project, a scientist shows that marine larvae, far from being mere floats, are almost acrobatic in their maneuvers to land on prime substrate, and therefore are much less at the mercy of fate than previously imagined.

Certain chemicals released from the seafloor are now believed to induce larvae to descend. That is, larvae can "sniff" chemicals in seawater—even very dilute amounts. These chemicals, called settlement inducers, help explain observations of larvae clusters on preferred substrates.

The Project

California Sea Grant funded Dr. Richard Zimmer of the University of California at Los Angeles to identify settlement inducer compounds in larvae of the California red abalone and Eastern oyster—high-value shellfish whose wild populations are at, or near, their historical lows.

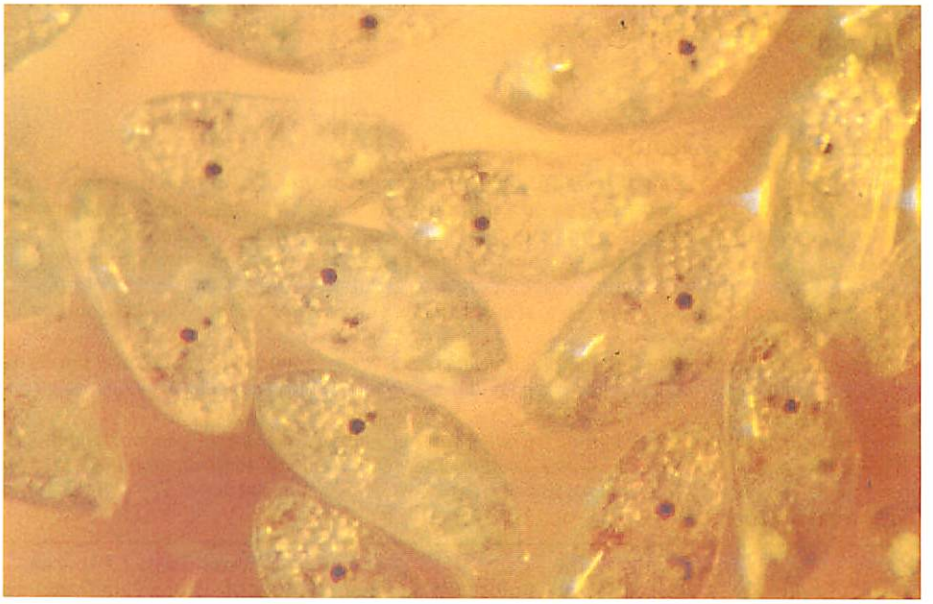
Method

Using a number of molecular techniques, including hollow fiber dialysis and liquid chromatography, Dr. Zimmer and colleagues were able to characterize these compounds in oyster larvae.

In a subsequent analysis, oyster larvae were shown to respond to low molecular weight peptides (proteins), which have the amino acid arginine at the carboxy-terminus. In field experiments, the same compounds were shown to attract barnacle larvae as well.

Dr. Patrick Krug, a postdoctoral researcher working with Dr. Zimmer, described the chemical signals as "akin to someone smelling cookies baking and wanting to stay in the kitchen."

In further experiments, the researchers made synthetic versions of the inducer compounds, predicted from computer models to be among the most powerful attractants. They found that the most powerful agent for inducing larval settlement was a chemical called GGR (glycyl-glycyl-L-arginine), which mimics the cues released by adult oyster reefs in nature. To verify the attracting power of GGR and the other synthetic molecules, the scientists tested 53 different compounds on live oyster larvae. They then used another set of computer models to develop a gel that releases GGR at the same rate as real oyster beds. This gel was placed in collecting trays to test GGRs



Barnacle larvae do not merely drift with ocean currents. By waving their cilia, they can issue a controlled descent onto perferred bottom habitats. Sea Grant research has shown that their descent is triggered by chemical cues from rock reefs. Photo: UCLA.

attracting power in laboratory and controlled field experiments.

In laboratory experiments, larvae were observed to position themselves near the GGR source. Dr. Zimmer said, "They dive bomb downwards by moving their little bands of cilia—little hairy whips on their exterior. They can coordinate their cilia and go where they want. It is pretty amazing for being so small. They are only about one-hundredth of an inch long."

In the field, scientists learned another amazing fact: the GGR gel attracts not only oyster but also barnacle larvae. Zimmer said, "They (the barnacles) settled like crazy." Settlement rates were enhanced about tenfold.

Dr. Zimmer's experiments are the first to show that larvae can settle in response to waterborne chemical cues under natural flow conditions.

For red abalone, the researchers were unable to identify natural, waterborne settlement inducers, so they changed their focus to investigate the chemical signals that enhance fertilization of male and female gametes. These experiments showed that red abalone eggs release a chemical that helps sperm navigate—and spurs them to swim faster near an egg. This chemical has been isolated and partially characterized through nuclear magnetic resonance studies.

Zimmer said of the compound: "What is so exciting is that the molecular structure of the attractant is remarkably similar to that of the mammalian neurotransmitter, serotonin. There may be strong homology between the receptor systems that modulate activity in the brain of a mammal and that operate the attraction of sperm and egg in an animal like red abalone. It appears that certain features of chemical recognition systems have been widely conserved throughout evolution."

Their abalone work also has implications for management of this highly depleted, once valuable, fishery. Dr. Krug said, "For red abalone, the bottleneck in their recovery may not be about larval settlement and finding the right bottom habitat. It is likely that the density of gametes is too low to ensure fertilization."

Applications

Inducer compounds can be used to promote colonization of certain habitats by commercially and ecologically valuable marine organisms. In theory, knowledge of the molecular structures of these compounds may be used in reverse to develop compounds that repel unwanted larvae, such as barnacle larvae that colonize boat hulls.

Cooperating Organizations

Bodega Marine Laboratory
California Department of Fish and Game
Cultured Abalone, Inc.
Los Angeles County Wastewater Management Treatment Plant
The Abalone Farm
Virginia Institute of Marine Science

Publications

Browne, K.A., and R.K. Zimmer. 2001. Controlled field release of a waterborne chemical signal stimulates planktonic larvae to settle. *Biol. Bull.* 200:87–91.

Krug, P.J., and R.K. Zimmer. 2000. Developmental dimorphism and expression of chemosensory-mediated behavior: Habitat selection by a specialist marine herbivore. *J. Exp. Biol.* 203:1741–1754.

Krug, P.J., and R.K. Zimmer. 2000. Larval settlement: chemical markers for tracing production, transport, and distribution of a waterborne cue. *Mar. Ecol. Prog. Ser.* 207:283–296.

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Decho, A.W., K.A. Browne, and R.K. Zimmer-Faust. 1998. Chemical cues: Why basic peptides are signal molecules in marine environments. *Limnol. Oceanogr.* 43(7):1410–1417.

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Sea Grant California

EDUCATION

E/G-12PD: 11.1.1998–8.31.2000

Innovative Tools for Educators: An Interactive Online Atlas of Ocean Productivity

Wolfgang H. Berger

Director, California Space Institute, University of California, San Diego

Summary

Led by the director of the California Space Institute, Dr. Wolfgang Berger, a team of researchers, teachers and students developed an educational website, highlighting topics such as the role of global climate on the ocean's biological productivity. The website, called Earthguide, is located at http://earthguide.ucsd.edu.

Earthguide's creators describe the site as "an online multimedia resource for busy people who want to know more about how the earth works." The site is geared to community college students in introductory earth science classes, although the site's visually captivating design and nontechnical explanations lend themselves for use in high school and grade school classrooms, too.

Earthguide has also been an effective tool for enhancing communication between university scientists and teachers. Earthguide's content is guided by an advisory panel composed of instructors from community colleges in the San Diego region, and the University of San Diego.

Earthguide contains many sections, including a news page, an image library, an ocean atlas, a brainteaser question, a collection of children's poems on the sea, and an extensive section on diatoms—single-celled algae that form the base of the food chain.

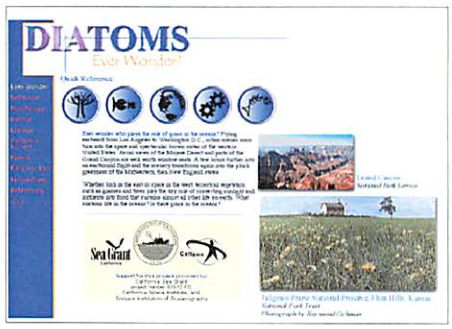
Diatoms are used as an object lesson in ecosystem dynamics. Through diatoms, students are shown how changes in ocean water temperatures change diatom populations, which in turn change fish abundance. The intent, Dr. Berger said, is to "improve public literacy in issues related to marine productivity by making current scientific knowledge and materials from the research community accessible."

Dr. Berger plans to expand Earthguide. Future projects include creating a curriculum that uses real ocean data to illustrate how El Niño and La Niña events alter the productivity of the California Current. He and colleagues also plan to incorporate satellite images of ocean color and wind into the atlas and to continue hiring undergraduate students to work on the design, content and computer programming of new webpages.

As the project evolves, students will be able to generate color-coded maps showing the distribution of various oceanographic parameters, including temperature, salinity and dissolved oxygen. These contour maps help students visualize oceanic processes while introducing them to standard data analysis techniques.

Earthguide was exhibited at the San Diego Science Educators Association Conference in San Diego in March 2000. The project will be presented as a "Centennial Contribution" to Scripps Institution of Oceanography, which turns 100 in 2003.

With Sea Grant funding, Dr. Wolf Berger and college interns created an educational webpage on diatoms for high school and community college teachers. Photo: Memorie Yasuda, University of California, San Diego.



The home page for "Diatoms: Living Opals," an interactive website designed to facilitate a self-guided exploration of the marine realm.

Cooperating Organizations

California Space Grant
California Space Institute
Grossmont Community College
Mira Costa Community College
Palomar College
University of San Diego

Publications
Yasuda, M., and W. Berger. 2001.
Earthguide website
http://earthguide.ucsd.edu/demo/seagrant/
http://earthguide.ucsd.edu/diatom/d1.html
http://earthguide.ucsd.edu/earthguide/
diagrams/levitus/

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E/UG-5PD:03.01.2000 to 9.30.2001

Assessing Sanctuary Shorelines: A Role for High School Students in Resource Management

John Pearse
University of California, Santa Cruz

The goal of this project is to develop a set of protocols for monitoring marine organisms living in the rocky intertidal habitats of the Monterey Bay National Marine Sanctuary, an area that stretches from San Luis Obispo to San Francisco. What distinguishes this project, called the Seymour Intertidal Monitoring Program, from others is that it is being designed to be carried out by high school students—not just as a learning experience for their benefit but also as a real contribution to professional science.

Background and Application

The rugged Central California coastline has one of the world's most productive and diverse intertidal zones. Within the region, however, there is remarkable spatial and temporal variation in species diversity, distribution and abundance. Although regional patterns have been documented, little is known about local, site-specific, variations. This was pointedly illustrated after an oil spill in the Santa Barbara Channel in 1969. Although it was indisputable the spill had devastated marine biota in some locations, a more quantitative assessment of damage was impossible because of the absence of a detailed marine census.

A student participating in the monitoring program logs her observations. Photo: UC Santa Cruz.

Emeritus biology professor John Pearse, center, helps students speciate and count intertidal organisms in the Santa Cruz area. Photo: UC Santa Cruz.

This project, if successful and sustained over time, will provide a baseline for detecting change in the future. This will make it possible, for example, to evaluate the impacts of disaster, as well as the effects of physical oceanographic changes—rising sea levels and ocean warming —on intertidal life.

The Project

The project is the brainchild of emeritus biology professor Dr. John Pearse of Long Marine Laboratory at University of California, Santa Cruz, who has for years led college students on trips to local tide pools and taught marine field courses. For this Sea Grant project, he adapted his college curriculum for high schoolers. Instead of memorizing the Latin names of legion marine organisms, students are taught to recognize the major and relatively easy-to-identify intertidal organisms – anemones, starfish, limpets, abalone, mussels and some types of marine algae. In effect, they are learning the natural history of local intertidal life. "They learn the things that are there, practice sampling on another visit and then on the next visit, begin counting," Pearse said.

In addition to counting animals, the students are taught how to plot species abundance as a function of grid location. From this, they see for themselves that intertidal marine animals tend to live in bands corresponding to the three zones of the intertidal: the high-zone, exposed to air most of the time; the mid-zone, rhythmically submerged and exposed by the daily tides; and the low zone, almost always submerged.

So far, Pearse and his team have worked with teachers and students from Aptos High School, Harbor High School, Watsonville High School, the Monterey Academy of Ocean Sciences, Santa Cruz Homeschool Association, Pacific

Collegiate School, Stewards of Save Our Shores, San Lorenzo High School, and Santa Catalina School for Girls.

Much of the survey work has been located at a model site at Natural Bridges, which has been periodically monitored by college students for 24 years. Pearse has also begun to develop monitoring protocols at Davenport Landing, Wilder Ranch State Park, Soquel Point and Almar Street in Santa Cruz, and Point Pinos in Monterey.

Applications

Besides the project's value as an educational tool for both teachers and students, the Monterey Bay National Marine Sanctuary has begun including its results in its overview of marine surveys in the region.

Pearse said, "My dream is that students will one day be able to plug in their data (into a computer) and compare it to what their parents got."

As a first step in making this happen, he is building an interactive, educational website (at www2.ucsc.edu/simp/index.html) that will store the students' tallies in a central database connected to the Seymour Marine Discovery Center website of the University of California, Santa Cruz.

Media Coverage

The Santa Cruz Sentinel ran a feature story on the project, titled "Students Get Their Feet Wet in Intertidal Monitoring Project," on November 19, 2000. Marilyn Reigler, host of radio station KUSP, interviewed Dr. Pearse and four participating students on *Prime Time at Noon* on April 12, 2001.

Cooperating Organization

Monterey Bay National Marine Sanctuary

Trainee

Osborn, Dawn, doctoral student in the Department of Ocean Sciences at the University of California, Santa Cruz. Osborn is studying the role of geology on intertidal ecology.

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R/E-54-PD: 12.1.1998–11.30.2000

Encouraging Learning Through an Exploration of the Sea

Miriam Polne-Fuller
University of California, Santa Barbara

Objective

The goals of this project were threefold:

- to teach young students basic science skills through an exploration of the wonders of the marine world;
- to expose students to academic research; and,
- to encourage students to pursue careers in the marine sciences.

Summary

Dr. Miriam Polne-Fuller, a marine biologist at the University of California at Santa Barbara, received funding to support an educational outreach program for K-12 students. Under her direction, children from area schools worked with professional marine scientists on a variety of laboratory experiments. The 32 students who participated in the program were also taken on educational field trips to local beaches and wetlands, where they learned first hand about the natural history of the coastal environment. The students, in grades two through eight, were selected from schools where a majority of families qualify for federally subsidized school lunches. These schools serve a predominantly Hispanic community.

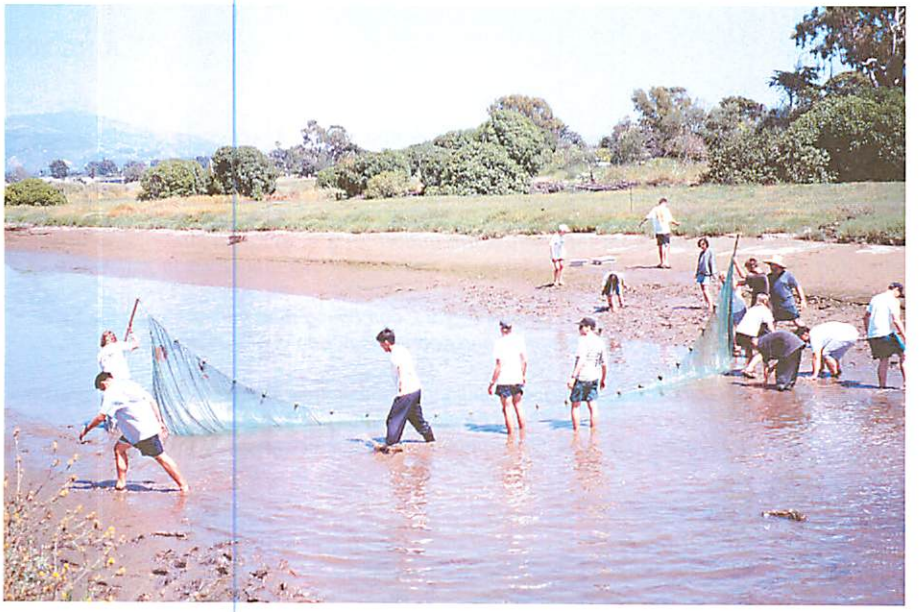
The Project

Elementary students conducted cell biology experiments that highlighted the sensitivity of marine cells to changes in temperature, salinity, light intensity and water quality. In one experiment, titled "Do Any Living Cells Truly Enjoy a Teaspoon of Beer?" students gazed under microscopes to observe the effects of alcohol on cell processes.

A fifth grader in one of Dr. Polne-Fuller's programs works under a sterile laboratory hood, testing antibiotic properties of seaweed extracts.

Older students studied the ecology of the giant kelp forest. Through this examination, they learned about photosynthesis and the physics of floating kelp stands. They also studied the chemistry of the sugars produced by kelp.

In addition to working with students, Dr. Polne-Fuller and collaborating teachers wrote educational materials on four different topics: the kelp forest, bioluminescence, marine worms as environmental monitors, and sandy beaches. The materials are designed to teach basic science skills targeted by the state's Science Standards and to expose students to ongoing research at the university.



Since the 1980s, California Sea Grant has helped support the award-winning "Young Marine Scientists" and "Teachers as Scientists" education programs created by Dr. Miriam Polne-Fuller of the University of California. Above, a group of high school students in the Summer Research Mentorship Program study a population of young fish in a local wetland. Photos: Dr. Miriam Polne-Fuller, University of California, Santa Barbara.

Collaborations

The University of California at Santa Barbara also supported this project through a Faculty Outreach Grant and a Young Marine Scientist

Grant. In the past, her programs have received funding from the Professional Association of Diving Instructors, also known as PADI, and from the Boyd Foundation. California Sea Grant has awarded her two previous grants to support her efforts to educate traditionally underrepresented students in marine science disciplines.

Dr. Polne-Fuller continues to work with middle and junior high school science teachers in the Santa Barbara County School District. In recognition of her unique commitment to teaching and outreach, Dr. Polne-Fuller was awarded the 2001 Alumni Association Teaching Excellence Award from the University of California, Santa Barbara.

Cooperating Organizations

California Department of Fish and Game

U.S. Army Corps of Engineers

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R/E-71PD: 7.1.2001–10.31.2001

Supporting an Educational Marine Science Camp for Urban Youth

Steve Strand
University of California, Los Angeles

Background

With support from Sea Grant, the UCLA Ocean Discovery Center operates educational marine camps for children in summer programs run by the Boys & Girls Clubs in the Los Angeles area. Sea Grant has funded Sea Camp every year the camp has offered programs.

The goal of Sea Camp is to teach inner-city and under-represented youth, many of whom have never been to the beach, about the plants and animals living in Santa Monica Bay. Through hands-on activities, students learn about the many kinds of interactions between people and coastal ecosystems. These day-long summer programs complement the UCLA Ocean Discovery Center's school-year programs for students.

The camp also serves as a classroom for science teachers, who participate as camp counselors. Activities are designed to help teachers develop curricula that meet California State Science Standards.

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

The UCLA Ocean Discovery Center, located at the base of the Santa Monica Pier in Los Angeles, is a public aquarium and marine science learning center, dedicated to educating K-12 students, as well as the general public, on the basic concepts of marine science and conservation. The aquarium is affiliated with UCLA and opened in 1996.

Campers display their projects. Photo: UCLA Ocean Discovery Center.

The Project

At Sea Camp, children are introduced to the biological, oceanographic and environmental conditions of the Santa Monica Bay through interactive presentations, slide shows, video presentations and a guided, hands-on exploration of marine artifacts—whale bones, shells and shark egg-cases—in the main part of the aquarium. They also are encouraged to touch live animals and peer inside the microscopic realm at the microscope lab.

The camp's activities vary from year to year, but in 2001 students were challenged to learn as much as they could about four marine organisms of their choice by observing animals and querying staff and docents. As part of the day's activities, students toured the Santa Monica Urban Runoff Recycling Facility, a one-of-a-kind operation that recycles runoff for use in commercial landscaping. Students were also taken on a field trip to a local beach, where they conducted a survey of marine debris and looked at the types of marine litter that marine animals may mistake for food.

In the summer of 2001, more than 600 children, aged from 5 to 17 years, participated in Sea Camp. These children came from areas as diverse as Santa Monica, Venice, Westchester, Inglewood, Compton,

Westminster and North Hollywood.

Dr. Steve Strand, director of the Ocean Discovery Center, said of the camp: "These children discovered the marine environment and initiated a stewardship for the Santa Monica Bay. This experience increased their sense of awe, caring and responsibility for the ocean. It also opened the door for these children to explore opportunities available in the sciences."

Cooperating Organizations
Malibu Boys & Girls Club
Santa Monica Boys & Girls Club
Santa Monica YWCA
Venice Boys & Girls Club

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PUB. NO. CSG-ED-02-003 **JUNE 2002**

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Extension

Nothing in This Section

Sea Grant California

FISHERIES RESEARCH & DEVELOPMENT

R/F-170: 3.1.1997–8.31.1999

Recruitment Patterns in Red Sea Urchins: A Population Genetics Approach

Ronald S. Burton

University of California, San Diego—Scripps Institution of Oceanography

Background

Sea urchins are what are known as "broadcast spawners." Adults release their gametes into seawater, and fertilization occurs if there is a high enough density of gametes to ensure that female and male gametes meet.

What happens after fertilization is something of a mystery. Scientists do not, for instance, know how far, on average, larvae travel during the six-week period it takes for them to develop and settle onto the seafloor. And, they do not know the degree to which ocean waves and currents mix larvae originating from different geographic locales.

There are, though, two possible scenarios at the far ends of a continuum of possibilities. One is that larvae are carried great distances and tossed about along the way by oceanic processes. As a consequence, urchin larvae from different beds (populations) mix and subsequently share many of the same genetic characteristics. The other possibility is that larvae settle down close to where they were formed. Because there is no long-distance mixing of larvae, urchins from different populations may become genetically distinct.

Work conducted by Dr. Ronald Burton, a marine biologist at Scripps Institution of Oceanography, suggests that urchin populations are often genetically distinct.

Although the result may seem largely academic, genetic differentiation has real implications for managing the urchin fishery—the state's number one fishery by volume and value for nearly a decade beginning in the late-80s. In particular, it has significance for establishing scientific criteria for marine reserves and local management of kelp beds.

San Diego-based urchin diver Pete Halmay, president of the California Sea Urchin Harvesters' Association, weighs a half-a-day's catch at a dock in San Diego Bay. Urchins are harvested for their big golden gonads, known as "L.A. uni" in Japan. Photo: Christina S. Johnson, California Sea Grant.

Genetic homogeneity, for instance, suggests that urchin beds are replenished with larvae from a well-mixed "larval pool" in which case managing the fishery is largely about protecting key larval sources, such as places where high urchin density leads to high rates of fertilization.

Genetic heterogeneity, on the other hand, suggests that young urchins are descendents of urchins from nearby beds. In this case, the health of the fishery relies on there being many healthy local urchin beds. Since overharvesting can easily lead to a long-term decline in productivity at any particular locale.

The Method and Findings

For the project, Dr. Burton collected sea urchins from beds between Point Loma in San Diego and Fort Bragg in Mendocino County and then analyzed their genetic signatures at six gene loci, using a technique called protein electrophoresis.

This analysis showed that there was significant genetic differentiation among populations at five of the six gene loci examined. Genetic

differences on Nei's scale—a standard scale used to evaluate genetic variation—ranged from nearly zero to 0.078.

He also showed that the degree of genetic differentiation was unrelated to the location from which the specimen was collected. Neighboring populations often showed greater genetic differentiation than distant ones.

In addition, he showed that there was a high degree of genetic differentiation between different age groups of urchins from the same bed - an observation that is also consistent with genetic heterogeneity. Young urchins, defined as those less than 30 millimeters in diameter, appeared to be more genetically differentiated than adults sampled from the same beds.

Although the genetic patterns are relatively clear, the processes that are generating these patterns are not. There are three possible processes that may be acting alone or in concert. The first is that, through random processes, some adult urchins produce more offspring than others. The second is that some urchin beds produce more offspring than others, due to things like prevailing oceanic conditions. Lastly, some larval genotypes may have significantly higher survival rates than others.

Cooperating Organizations

California Department of Fish and Game
Catalina Offshore Products
San Diego State University
University of California, Davis

Publications

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Hamm, D.E., and R.S. Burton. 2000. Population genetics of black abalone, *Haliotis cracherodii*, along the central California coast. *J. Exp. Mar. Biol. Ecol.* 254:235–247.

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Hamm, D.E. 1999. Genetic divergence among populations of black abalone, *Haliotis cracherodii* along the central California Coast. M.S. thesis abstract, University of California, San Diego.

Moberg, P.E. 1998. Spatial and temporal genetic differentiation among populations of the red sea urchin, *Strongylocentrotus franciscanus*. M.S. thesis abstract, University of California, San Diego.

Trainees and Theses

Moberg, Phillip, M.S. in Marine Biology, Scripps Institution of Oceanography, University of California, San Diego, 1998, "Population Genetics of the Red Sea Urchin Along the California Coast."

Hamm, David, M.S. in Marine Biology, Scripps Institution of Oceanography, University of California, San Diego, 1999, "Genetic Differentiation among Black Abalone Populations."

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R/F-174: 5.1.1998–5.31.1999

Validating Age Estimates for Bocaccio Rockfish with Radiometric Dating

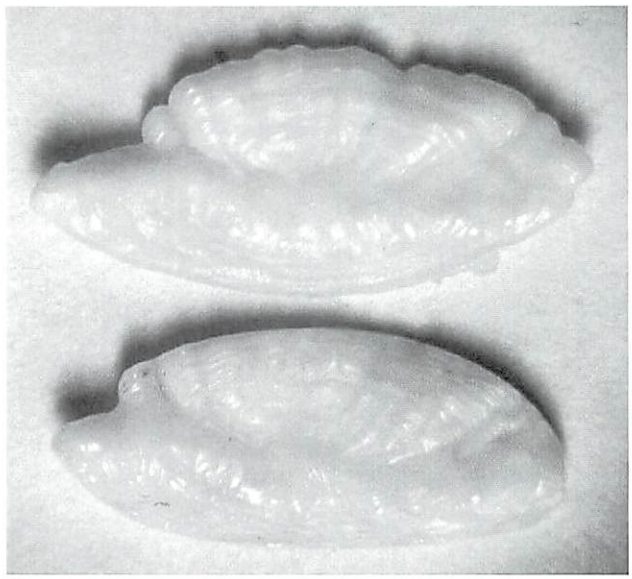
Gregor M. Cailliet

California State University—Moss Landing Marine Laboratories

Summary

Bocaccio (*Sebastes paucispinis*), also known as red snapper, rockcod, grouper or salmon grouper, were the dominant rockfish in California's early longline fishery and the most abundant rockfish in the bottom-trawl fishery from Morro Bay to Fort Bragg until the mid-1980s, according to a 2001 report published by the California Department of Fish and Game. Annual landings of bocaccio are now about a hundredth of what they were in the early-1970s. The National Marine Fisheries Service estimates that the stock's spawning biomass has been reduced by about 98 percent.

As with other long-lived fish, bocaccio are especially vulnerable to overexploitation: they reach sexual maturity late in life, and their reproductive success rate is highly variable from year to year. Another factor contributing to their decline has been the absence of accurate age statistics, which fisheries managers may use to compute sustainable catch limits.



An otolith is a bone-like structure in a fish's ear, assumed to calcify in annual layers. The number of layers is thus a proxy for a fish's age. The otolith on top is estimated to be from a 3-year-old bocaccio while the one on the bottom is estimated to be from a 28-year-old. Photo: Allen Andrews.

The Project

In this project, California Sea Grant funded Dr. Gregor Cailliet and colleagues at California State University to evaluate the accuracy of aging bocaccio by counting calcified layers in the fish's bone-like ear structures, called otoliths. Otoliths are assumed to grow in annual bands.

Their work suggests that otolith-based age estimates tend to underestimate ages of older fish, compared to age estimates based on radiometric analyses. In younger fish, whose otolith layers are more distinct and easy to count, both methods provide similar age estimates.

The scientists' findings are based on measurements of the ratios of radium 226 and lead 210 in more than 370 pairs of otoliths from bocaccio caught in Central California in 1983-84. In addition to aging specimens, they also computed life expectancies. Their analysis suggests that the life expectancy of a female bocaccio is at least 39 years while that of a male is at least 25 years. Previous estimates for females and males ranged from 20 to 50 years.

Applications

Dr. Cailliet's work rigorously documents the longevity of the bocaccio and suggests that the fish are more vulnerable to overfishing than previously thought. As a result, the stock probably requires a longer recovery period than originally thought. The techniques developed for this project are being applied to other species of management concern. Dr. Cailliet currently is funded to validate age statistics for the blackgill rockfish. He plans to study age statistics for the orange roughy in New Zealand and the Patagonian toothfish (Chilean seabass) in the Southern Ocean, two other long-lived species whose numbers have declined dramatically in recent years. Some of his previous Sea Grant research showed that the yelloweye rockfish can live for more than 100 years.

Cooperating Organizations

Monterey Bay Aquarium
National Marine Fisheries Service
University of California, Santa Barbara

Publications

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Trainee and Thesis

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Sea Grant California

FISHERIES RESEARCH & DEVELOPMENT

R/F-43PD: 11.1.1998–10.30.2000

First Known Sightings of the Withering Syndrome Bacterium Discovered North of San Francisco

Carolyn Friedman
University of Washington

Summary

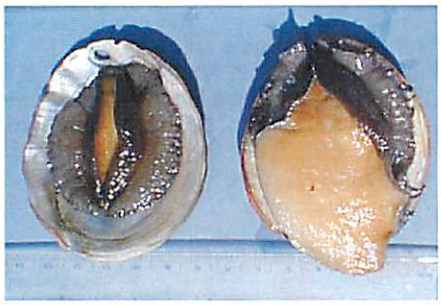
Populations of California's seven native abalone species have been reduced not only by overharvesting but also by disease. One of the most lethal diseases is a waterborne bacterial infection that causes what is known as withering syndrome. Withering syndrome obstructs the production of digestive enzymes. To prevent immediate starvation, abalone catabolize, or destroy, their own foot muscle, causing their body to atrophy or wither, hence the name. The consequence of the disease can be extreme: black abalone populations in Central California were reduced by as much as 99 percent by withering syndrome in the mid-1980s.

Up until recently, the withering syndrome bacterium *Candidatus Xenohaliotis californiensis* was believed to be confined to warmer ocean waters south of San Francisco. A survey of abalone beds, conducted by fish pathologist Dr. Carolyn Friedman, however, has revealed that the bacterium has spread to two isolated locations in colder northern waters. Her work suggests that human activity—aquaculture practices or abalone "outplantings"—may have contributed to the spread of the bacterium.

The Project

Dr. Friedman and colleagues collected red and black abalone specimens from 13 sites in Northern and Central California between December 1998 and October 2000.

Analyses of tissue samples revealed that the withering syndrome bacterium was present at two sites north of San Francisco: Crescent City near the Oregon border and Van Damme State Park in Mendocino County. Although none of the abalone from these two sites showed signs of withering syndrome, there are concerns that the infected abalone, by dispersing the bacterium via their feces, increase the potential for an outbreak later.



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.

Both Crescent City and Van Damme State Park received abalone "outplantings," in which abalone seed bred in captivity were transferred to the ocean. Crescent City is also located near an aquaculture farm that imported abalone from farms now known to have had infected abalone.

Impacts

Withering disease not only threatens wild stocks but also farm-raised abalone, which may be reared in cages in the ocean or in land-based tanks that circulate ocean water through them.

California has 12 abalone farms, with the bulk of production coming from four farms. The state's cultured abalone crop has an estimated value of $4 million to $5 million a year.

Dr. Friedman is currently involved in developing antibiotic therapies for

At any given time, The Abalone Farm, Inc. in Cayucos, California, may have about 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. Photo: Ray Fields, The Abalone Farm, Inc.

farm-raised abalone. She is also working with industry to develop ways of administering antibiotics orally in abalone feed. Another goal is to understand how environmental stresses, such as a lack of food or warmer than normal water temperatures, may trigger withering syndrome in abalone that already harbor the withering syndrome bacterium.

Cooperating Organizations
Abalone International, Inc.
California Aquaculture Association
California Department of Fish and Game

Publication
Finley, C.A., F. Wendell, and C.S. Friedman. 2002. Geographic distribution of *Candidatus xenohaliotis californiensis* in northern California abalone. *J. Shellfish Res.* In press.

Trainee and Thesis
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Sea Grant California

FISHERIES RESEARCH & DEVELOPMENT

R/F-181: 7.1.2000–6.30.2001

Characterizing Fisheries Habitat Along the California Continental Margin

Gary Greene and Rikk Kvitek

San Jose State University—Moss Landing Marine Laboratories; California State University, Monterey Bay

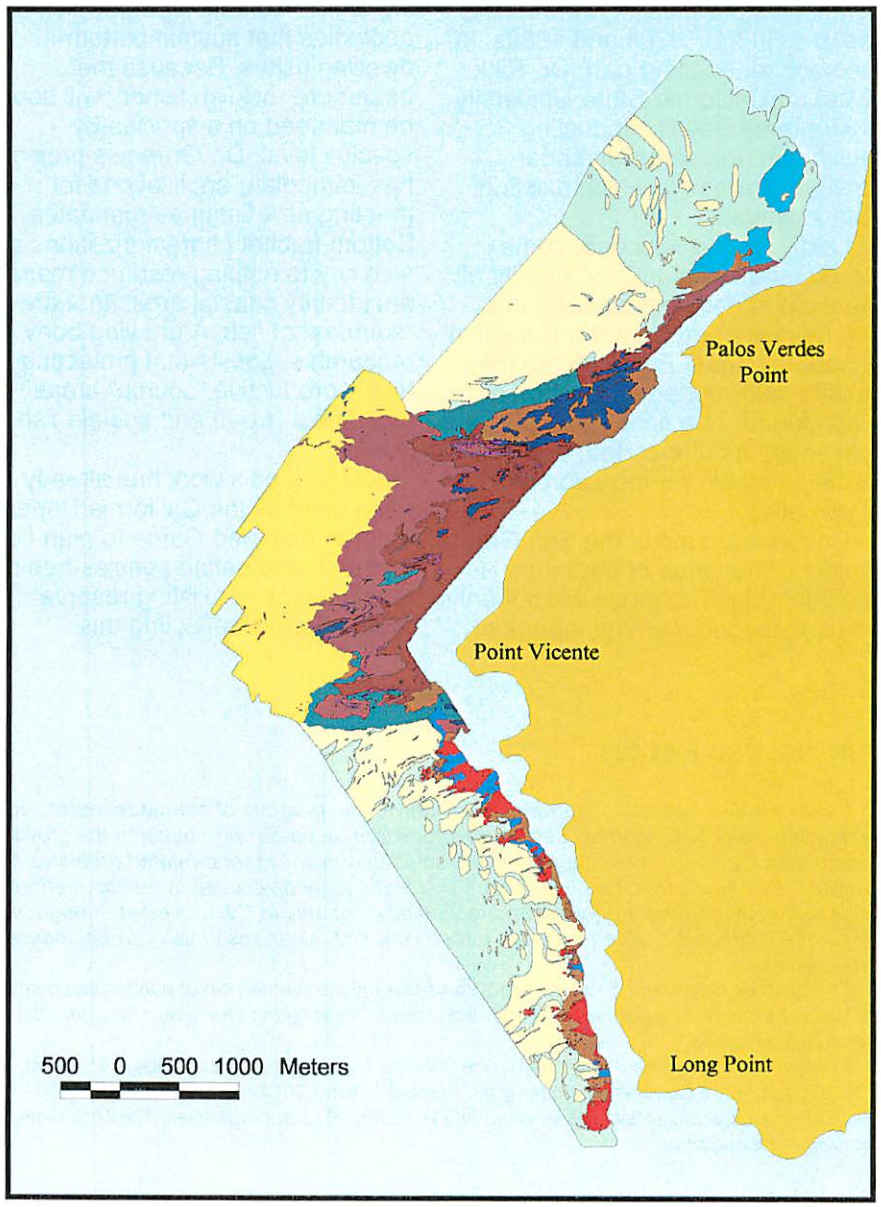
Background

Biologists have long recognized that fishes are not uniformly distributed up and down the coast but instead congregate in certain environments. This somewhat obvious fact has gone relatively unstudied because of the technical difficulties of imaging underwater landscapes. With advances in underwater vehicles and sonar imaging techniques, however, biologists now have the tools they need to map the benthic habitats that sustain the state's bottom-dwelling fishes.

Such information not only satisfies scientific curiosity but aids resource managers charged with implementing two state mandates: the Marine Life Management Act, which requires the California Department of Fish and Game to develop species-by-species management plans for rockfish (species that typically inhabit rock-bottomed areas), and the Marine Life Protection Act, which calls for the agency to consider establishing a network of no-take reserves. Additionally, habitat maps benefit federal fisheries managers charged with delineating essential habitat areas for finfish and shellfish species, under the Magnuson-Stevens Fishery Conservation and Management Act, and the Sustainable Fisheries Act.

The Project

Marine geology professor Dr. Gary Greene at the Moss Landing Marine Laboratories was funded to produce a series of marine benthic maps for California's continental margin. These maps, a first of their kind, identify distinct features on the seafloor—submarine canyons, rock outcrops, pinnacles, boulders, sand,



The map, above, shows benthic fish habitats off Point Vincent in Rancho Palos Verdes, produced by Dr. Gary Greene of Moss Landing Marine Laboratories from multibeam and back-scatter acoustic images. Different habitat areas are color-coded. Green, for instance, stands for "soft unconsolidated sand and gravel," brown for "hard deformed differentially eroded bedrock."

Image: Joe Bizzarro, Moss Landing Marine Laboratories.

mud and gravel—that provide critical habitat for species of management concern.

This two-year project, now in its final year, has three distinct parts. In the first, which has been completed, Dr. Greene and colleagues collected and analyzed previously proprietary industry data on the seafloor's topography and composition. The bulk of this data comes in the form of sonar images collected by oil companies prospecting for offshore reserves in the 1970s and 1980s. In the second, ongoing part, Dr. Rikk Kvitek of California State University at Monterey Bay is conducting multibeam and sidescan sonar surveys of areas in which existing data is sparse.

Lastly, as the new data come in, Dr. Greene will manually identify all the various geologic features that can be discerned from the collection of sonar images. Features are then circled, color-coded and put on a map legend. The final maps will be presented in color-coded, GIS format, suitable for inclusion in a digital atlas.

Dr. Greene said of the Sea Grant project: "The value of the maps is considerable. The maps will not only be used for fisheries management, but they will be invaluable in the selection of marine protected areas.

"With the maps, resource managers can identify candidate sites in areas that may be most attractive to the various rockfish that may be endangered."

Applications

The marine benthic maps being produced through this project provide the foundation for identifying critical benthic topographies and geologies that sustain bottom-dwelling fishes. Because the nearshore rockfish fishery will soon be managed on a species-by-species level, Dr. Greene's project has immediate applications for meeting new fisheries mandates. Bottom habitat characterizations are also key to helping resource managers identify coastal areas that are "sources" of fish. A growing body of research suggests that protecting highly productive "source" areas could help revive and sustain fish stocks.

Dr. Greene's work has already been used by the California Department of Fish and Game to plan field research and define species-habitat relationships in existing reserve areas. Further reflecting this project's relevance for fisheries management, much of the information from this project will be incorporated into the California Department of Fish and Game's atlas of fish habitat maps.

Telecommunication companies including MCI and AT&T have also requested copies of the final maps, as have government agencies such as the U.S. Navy, National Marine Fisheries Service, and the California Division of Mines and Geology. Canada plans to duplicate Dr. Greene's methods in a parallel effort to identify key habitats for bottom-dwelling fish.

Cooperating Organizations

California Department of Fish and Game
California Division of Mines and Geology
Monterey Bay Aquarium Research Institute
U.S. Geological Survey

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PUB. NO. CSG-F-02-003 **AUGUST 2002**

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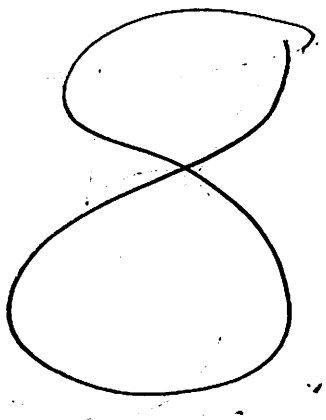
Marine Affairs



Nothing in This Section

Sea Grant California

MARINE NATURAL PRODUCTS

R/MP-79: 3.1.1998–8.31.2001 and R/MP-89: 3.1.2000–2.28.2002

Frontiers in Squid Reproduction: Prospecting for New Antibiotics

David Epel
Stanford University—Hopkins Marine Station

Background

Many strains of disease-causing bacteria have become resistant to antibiotics, leading those in the medical profession to search for new sources of drugs.

Although most antibiotics have been derived from terrestrial life, it is the marine world that may provide the pharmaceutical industry with the next generation of medicines. The biochemistries of seemingly simple marine organisms such as blue-green algae, sponges and squid are inspiring new ideas for drug development.

The Project

Marine biology professor Dr. David Epel of Stanford University was funded to study the anti-microbial properties of coatings on squid egg sheaths. Recent studies have shown that female squid inoculate their eggs with a paste that protects the eggs from fungi, bacteria and parasites during their one-month incubation on the seafloor.

It is hoped that these protective coatings work through biochemical pathways that have not been seen in terrestrial animals. Such compounds offer the best defense against a growing number of antibiotic-resistant diseases.

A female lays her eggs. Photo: © Sea Studios Foundation.

In previous Sea Grant research, Dr. Epel's laboratory isolated two novel types of bacteria—a *Shewanella* sp. and *Roseobacter* sp.—from the eggs and accessory nidamental glands of the California market squid (*Loligo opalescens*). The accessory nidamental glands are reproductive organs located beside the egg-producing nidamental glands. They also harbor a dense bacterial community that is secreted onto the eggs. These bacteria are collected from seawater by female squid.

In this project, Dr. Epel and post-doctoral researcher Dr. Todd Ciche continued their examination of these protective bacteria, using a molecular technique that allows them to identify all the different types of bacteria present on squid eggs.

Using this new technique, Drs. Epel and Ciche have discovered about eight previously unknown kinds of bacteria in the egg sheath of the market squid. The researchers have also succeeded in growing most of these new bacteria in culture. In earlier experiments, they were unable to do this.

The Findings

Only one of the 10 bacterial species was shown to produce anti-bacterial compounds. Based on this, the scientists hypothesize that the group of bacteria work in concert, communicating through chemical signals, to produce antibiotic and anti-fungal compounds. Thus, although most bacteria may not directly produce protective compounds, they may play a key role in signaling other bacteria to produce them.

Accessory nidamental gland showing concentrations of bacterial pigment. Photo: Dr. David Epel, Stanford University.

In subsequent experiments, Drs. Epel and Ciche have characterized the bacteria in the egg coatings of two other species of squid—one native to Hawaii and the other native to the Mediterranean Sea. Although the squid species have geographically distant ranges, their egg sheaths contain several of the same bacteria found in the sheaths of the California market squid. The finding suggests that these common bacteria are involved in a common biological process, and that the bacteria and their protective func-

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

tion have remained unchanged during the many millions of years it took for the different squid species to evolve.

Drs. Epel and Ciche's future work will focus on isolating and describing the antibiotics present in the egg coatings. They also plan to study the communication mechanism among the different species of bacteria.

Cooperating Organizations
Monterey Bay Aquarium Research Institute
School of Fisheries, University of Kyoto, Japan
University of Hawaii
University of Wisconsin

Trainee and Thesis
Eufemia, Nancy, Ph.D. in Biology, Department of Biological Sciences, Stanford University, December 2000, "The Role of the Multixenobiotic Resistance Mechanism (MXR), P-Glycoprotein, as a Protective Response Against Environmental Stress in Mytilus Mussels."

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R/MP-73: 10.01.1995–3.30.2000

Neuroinflammation, Finding A Marine Natural Product that Targets Microglia in Brain

Alejandro Mayer
Midwestern University, Illinois

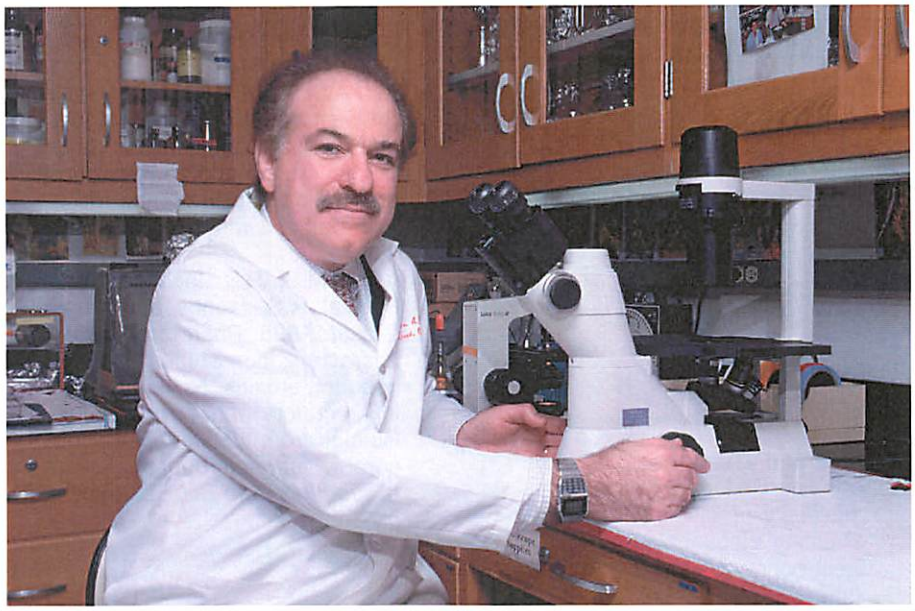
If you were to peer at brain tissue under a microscope, you would rarely see white blood cells, the body's main system of defense against infection and cancer. Their absence in the brain once led many to speculate, incorrectly, that the central nervous system must lack an immune system. In reality, it seems the brain has its own immunological sentries, a network of microglia cells that normally do not come into contact with white blood cells. This segregation of immunological duties protects the brain from neuron-damaging chemicals secreted by white blood cells.

What scientists have found out, however, is that secretions from microglia cells can also damage neurons. Normally, microglia cells have a benevolent effect. In their resting state, they vigilantly monitor the health of the neurons around them. In the event of infection or trauma, microglia cells become activated, changing shape, mobilizing and migrating to an injured area. In their battle against interlopers, they may secrete chemicals called mediators.

For reasons that are not fully understood, overzealous microglia cells sometimes deluge neurons with mediator compounds. As a result, they damage the neurons they are supposed to be protecting. It is currently believed that mediator compounds may exacerbate or help cause Alzheimer's disease, stroke and multiple sclerosis.

The Project

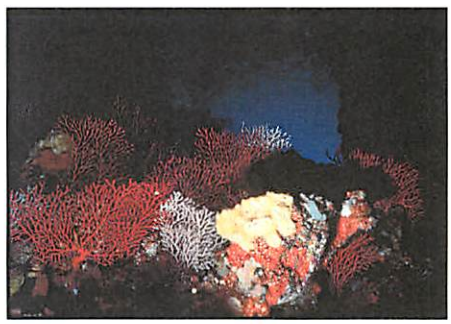
The purpose of this project is to investigate whether compounds extracted from marine organisms—soft corals, sponges, tunicates, algae and bacteria—suppress, inhibit or control the release of neurotoxic mediator compounds in the brain.



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.

Dr. Alejandro Mayer, a pharmacologist at Midwestern University in Downers Grove, Illinois was funded to conduct a pharmacological investigation of 38 compounds purified from marine organisms. Many of these pure compounds were provided by marine chemists, including Sea Grant researchers Drs. Robert Jacobs of UC Santa Barbara and William Fenical of UC San Diego.

Of the 38 compounds tested, three showed promise in drug discovery. These three all inhibited the release of a mediator known as thromboxane B2, a cause of neuroinflammation, and superoxide, a free-radical type of mediator that may help cause Alzheimer's disease.



The yellow sponge (*Haliclona sp.*) is the source of anti-inflamatory Manzamines. Photo: Tatsuo Higa, University of the Ryukyus, Okinawa, Japan.

Dr. Mayer's most exciting finding, however, was the discovery that the marine chemical Manzamine A, extracted from a marine sponge, inhibits mediator formation in microglia isolated from newborn rats without killing healthy cells.

Mayer has since patented the

anti-inflammatory uses of Manzamines.

Applications

Aspirin is an example of a nonsteroidal anti-inflammatory agent that relieves headaches by inhibiting the release of a certain type of lipid mediator in the brain. The hope is that Manzamines will lead to the development of a new class of nonsteroidal anti-inflammatory drugs that specifically target mediator production by microglia cells.

Cooperating Organizations

Abbott Laboratories
Harbor Branch Oceanographic Institution
SmithKline Beecham Pharmaceuticals
University of California
University of Guam
University of Mississippi

Trainee and Thesis

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Patent

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Mayer, A.M.S., S. Oh, K.H. Ramsey, P.B. Jacobson, K.B. Glaser, and A.M. Romanic. 1999. *Escherichia coli* lipopolysaccharide potentiation and inhibition of rat neonatal microglia superoxide anion generation: Correlation with prior lactic dehydrogenase, nitric oxide, tumor necrosis factor-a, thromboxane B2, and metalloprotease release. *Shock* 11(3): 180-186

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Sea Grant California

OCEAN ENGINEERING

R/OE-36: 3.1.1998–2.28.2001

Wave-Climate Risk Analysis: Predicting the Size, Frequency and Duration of Large Wave Events

Rodney Sobey
University of California, Berkeley

The most destructive ocean storms along the coast occur relatively infrequently.

The only way to predict the intensity, duration and frequency of large wave events is to reconstruct past events from historical data. Assuming past patterns repeat themselves, a process called extrapolation can then be used to make predictions about future events.

Extrapolation can provide reliable forecasts if the data record spans a suitably long period of time. Unfortunately, high-quality wave data goes back only two decades. This brief snapshot of oceanic conditions makes it nearly impossible to forecast events that may occur once every hundred years, even though it is precisely these infrequent, natural hazards that engineers should keep in mind when designing coastal structures.

With rising sea levels and continuing development along the shoreline, city planners and engineers face increasing pressure to evaluate the risk of erosion, landslides, and flooding from large wave events. Photo: Eric Hanauer.

The Project

The goal of this project was to develop new statistical and mathematical methods for predicting the risk of property loss, flooding, and erosion from large ocean storms. The cornerstone of the project was to develop a technique for extracting as much information as possible from wave data records. Standard analytic methods, in contrast, often discard useful information from data. The data used for the project was collected by the National Oceanographic and Atmospheric Administration's network of ocean buoys.

Standard wave-climate forecasts are based on analyses of "extreme value" wave events—that is, by collecting information on the largest wave heights in a given period of time, typically a year. A probability distribution function is then fit to a series of these extreme values. From this, scientists calculate the "exceedance probability" of a storm of a set magnitude and recurrence interval.

Sea Grant funded Dr. Rodney Sobey, a professor of civil engineering at the University of California at Berkeley, to examine a new, perhaps better, method for calculating these exceedance probabilities. The method is based on the assumption that storms nearly as big as the year's largest provide additional, usually untapped, information on wave-climate patterns.

Sobey's method employs what he calls "triple annual wave maximums," which means that he looks at the largest waves in each month and from these selects the three largest events in a year. These three maximum events are treated as independent and identically distributed random variables. More sophisticated mathematical methods are then used to incorporate information on the duration of wave events.

To test the accuracy of his method, he applied it to an 84-year record of rainfall in San Francisco. This was done by dividing the 84-year record into seven 12-year segments. He then applied his new method and traditional ones to the short-record segments, in turn comparing these predictions to those calculated from the full-length record, which he assumed represented the true values. His results showed that the triple annual method more closely matched the true values than standard methods.

In a second set of experiments, he applied his method to buoy data in the Gulf of Mexico, Atlantic and Pacific oceans. He then plotted the results of his analysis as sets of concise intensity-duration-frequency curves.

Applications

His results provide a technique for improving marine forecasting along the nation's shoreline. As urbanization of the coast continues, better forecasting is becoming an increasingly important tool for protecting property, avoiding flooding, and guiding emergency evacuation plans.

The U.S. Army Corps of Engineers' Research and Development Center plans to use the results of this project as a routine method for analyzing and presenting wave data.

Cooperating Organization

National Oceanic and Atmospheric Administration National Data Buoy Center

Publications

Sobey, R.J., and L.S. Orloff. 1998. Duration in wave climate analysis. In Coastal engineering '98, Proceedings of the American Society of Civil Engineers Conference, Copenhagen, Denmark. pp. 1013–1026.

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Winslow, Kyle, Ph.D. in Environmental Engineering, University of California, Berkeley, December 2000, "Turbidity Currents."

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