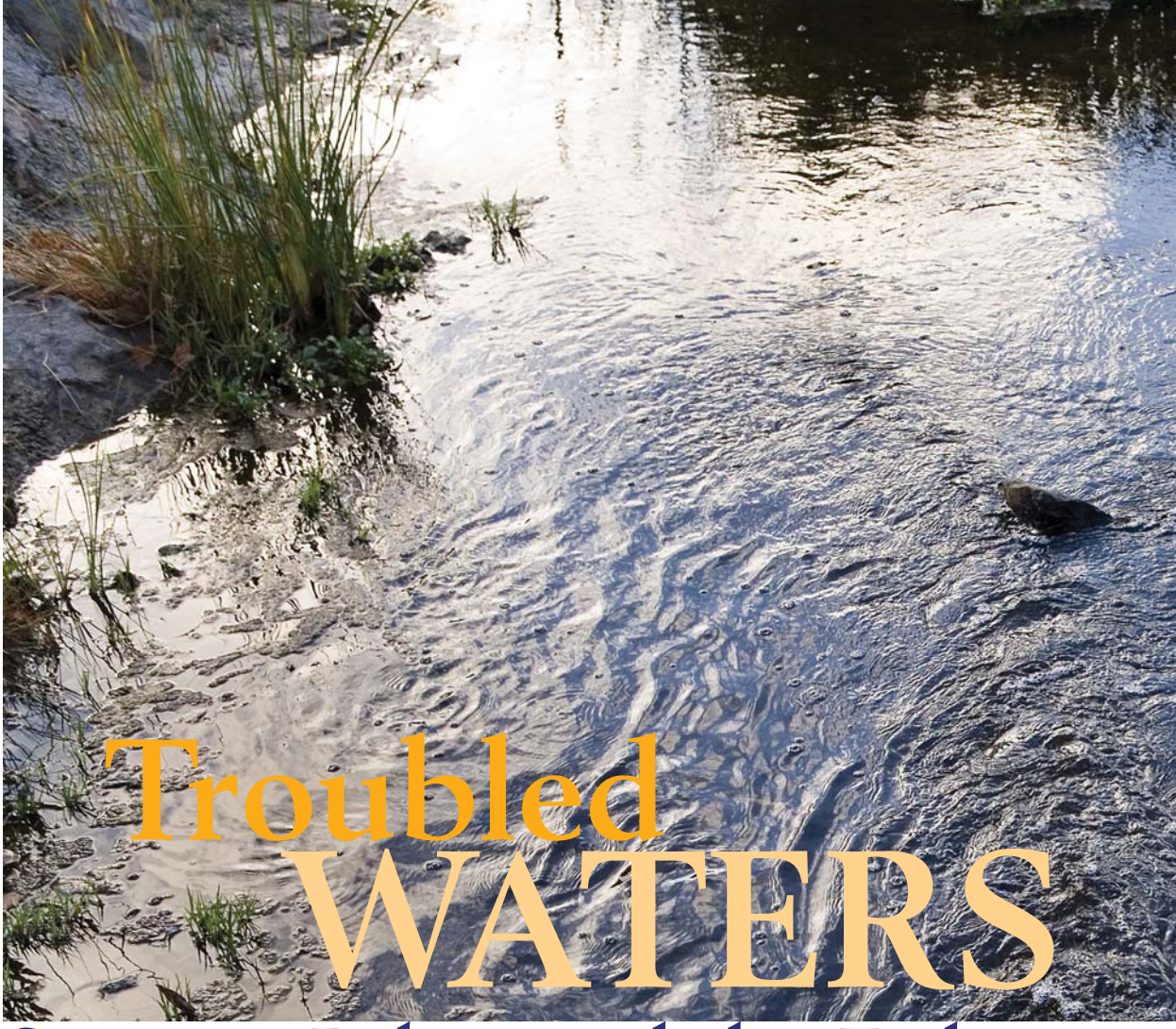
**Pollution. Drought. Overdevelopment. Overconsumption. SPH faculty, students and alumni lead the effort to keep our oceans, streams, wetlands and drinking water healthy, clean and abundant.**



# Troubled WATERS

## Science, Policy and the Fight to Preserve Our Natural Resources

For an essential natural resource, water – in our oceans, lakes, reservoirs, streams, wetlands or coming out of our taps – hasn't always gotten the protection it warrants.

The stakes are high. Clean water is critical for human health and ecosystem survival – a point that is particularly pronounced in the Los Angeles region, no stranger to droughts or closed beaches. Here, leaders in the scientific and policy struggles on behalf of our aquatic resources – many of them faculty, students, or graduates of the UCLA School of Public Health – report mixed results.

Significant progress has been made in the Santa Monica Bay, thanks in part to the science, education and advocacy of Heal the Bay, the nonprofit organization led by Mark Gold (D.Env. '94). In the 20 years since Heal the Bay was founded, plant and animal life has been restored to the "dead zone" that previously existed in the middle of the bay and the amount of sewage solids discharged into the bay has been reduced by 90%. Beach water quality during the summer has taken a dramatic turn for the better. But there is still a long way to go. "The biggest challenge before us is storm water runoff, where there has been little progress," Gold says. "The runoff is still found to be toxic to aquatic life almost everywhere it's tested, and our beaches look like landfills after every rain."

In September, the Los Angeles Regional Water Quality Control Board implemented the nation's most stringent bacteriological regulations for beach

water quality. In making the case to government officials, the board argued that any further delay in enforcing the stricter standards would carry substantial economic and public health costs. One of the key studies cited was published in July by Dr. Linwood Pendleton, associate professor of environmental health sciences at the school, who teaches in the Environmental Science and Engineering (ESE) program, an interdisciplinary, policy-oriented doctoral program based in the school.

On the downside, Pendleton's research focus is prompted by the reality that coastal waters are not always treated with the care they deserve. "People don't appreciate how important beaches are, because they're largely free," he says. "But they're an important part of the coastal economic engine. My work is pulling together how big that economic contribution is, and then looking into the damages to that economic contribution caused by having dirty water and closed beaches."

Exciting new technologies are being developed to treat drinking water – including a desalination process currently being studied by Dr. Mel Suffet and two of his students that could one day lead to a feasible way of treating water from the ocean so that it's acceptable for drinking. "I predict desalination of ocean water will be cost-effective in 10-20 years," says Suffet, professor of environmental health sciences and a member of the ESE faculty. "If that occurs, it could solve the water-quantity problems of Southern California. Of course, then we would really have to keep the ocean clean, and right now too many people don't care about that."

Water issues fall into two major classes: those that have to do with water that is treated, delivered and consumed by humans, and those related to water in the environment – from streams, lakes and reservoirs to coastal waters. In some cases there is overlap. Contaminants in a reservoir used for drinking water affect both the population that consumes it and the ecology it supports.

Faculty and students at the school are studying both classes of water issues. "We have people concerned with the chemistry – the effects of what goes into the water; the ecological consequences of these effects; and the human health and economic impact of these interventions," says Dr. Richard Ambrose, professor of environmental health sciences and director of the ESE program. Again, the distinctions often blur. When oceans are contaminated by bacteria from sewage spills or storm water, for example,

"The huge unknown is what's going to happen with global climate change. That covers every possible dimension —the quality of water and its sources, as well as what will happen from our local rainstorms. We may have more extreme storms and more flooding, as well as more droughts. All of these will have human and ecosystem consequences that will have to be dealt with."

— Dr. Richard Ambrose

the people who depend on the ocean's fish supply suffer along with the sea life.

Suffet, an environmental chemist, studies potentially toxic compounds and their effects on drinking water as well as on the ecology of streams and coastal waters. In his research on drinking water, he focuses not only on health concerns but also on palatability – studying compounds that, even if not unhealthful, may result in taste and odor problems. In one study, he is tackling the taste and odor problems caused by two nontoxic chemicals found in natural waters: geosmin and 2-methylisoborneol. Both are released by algae, making them a concern in Southern California wherever there are lakes and warm weather. The Metropolitan Water District of Southern California and the Los Angeles Water Department have begun using ozone at water treatment plants to remove these chemicals. Suffet is studying the effect of that approach, as well as strategies of adding chlorine or chloramines to minimize the flavor of these materials. He has also begun applying his work in drinking-water odor issues to air pollution, particularly from compost facilities and wastewater treatment plants.

Taste and odor are minor concerns in parts of the world where water is particularly scarce. An estimated 1.1 billion of the world's nearly 7 billion people lack access to clean water. Developing countries currently bear the brunt of the crisis, but if current trends continue, water scarcity could one day become a major problem for Southern California. "The global climate change models indicate that in the future we're going to get a much higher percentage of our precipitation as rain rather than as snow," says Ambrose. "Right now, one of nature's services is that it stores the water for us in the form of snow, and then releases it over an extended period of time so that we can use it. The Sierra Nevada snowpack is currently serving as a huge water reservoir, but if the precipitation comes in as rain, a lot of that water is going to fill the reservoirs to capacity, run out to the ocean, and not be available later in the year."

That's where the research of Suffet and others to improve water treatment technology comes in. Working with the Metropolitan Water District of Southern California, Suffet and his students are focusing their desalination effort on the Colorado River, a major source of water for the region that has experienced deterioration in quality as its chemistry changes and demand increases. Among other things, the salt content in the Colorado River water must be decreased to be acceptable for drinking. The ideal solution would involve the use of membrane filtration, but the technology's cost has been a barrier.

"The future of drinking water is developing membranes that are inexpensive and can be used by the water industry not only for desalination, but also

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— Dr. Linwood Pendleton

for removing bacteria, viruses, hazardous chemicals and chemicals that cause taste and odor problems," Suffet explains. "The key to the expense of the membrane is that it fouls or gets clogged and fails to operate for long periods of time." Suffet and colleagues are studying the fouling process in the hopes that a better understanding will help to identify ways to prevent it. They have found that a mixture of a high-molecular-weight natural background organic matter, humic material, fouls the small-sized membrane channels. In field studies in Yuma, Ariz., Suffet's group is exploring how to overcome that hurdle. "It's a long-term effort, but if we can get a handle on this, it could one day lead to making desalination of ocean water cost-effective," Suffet says.

As housing developments continue to go up in Southern California, water scarcity looms as a major issue, as do potential issues of contamination caused by urban runoff. Suffet heads another group working with Sweetwater Reservoir, which supplies the drinking water for Spring Valley and the surrounding area near San Diego. When rain runs off the soil and roads, it picks up pesticides and poly-aromatic hydrocarbons – carcinogenic compounds deposited by automobiles – and brings them into the reservoir. To combat this concern, Sweetwater created a wetland to intercede between the reservoir and the runoff and treat the water. Suffet's and Ambrose's groups are studying ways to optimize this urban runoff diversion system so that the pollution going into the reservoir is minimized.

Ambrose's work spans the gamut from water chemistry to human health, with a focus on how contaminants that are put into fresh water, often as a result of urbanization of watersheds, affect the health of ecosystems. In addition to studying ecosystem changes, he and his students are exploring how to assess their effects. "We need to determine how we should measure an ecosystem's health and how we can integrate that information to better understand the policies or management changes that would ensure that it remains healthy – or regains its

## Shannon Pankratz

Pankratz, a student in the interdisciplinary Environmental Science and Engineering (ESE) program, based in the School of Public Health, works with Dr. Mel Suffet in focusing on storm water runoff pollution. Two storm water sampling projects that she has been involved in, locally for Ballona Creek and at Sweetwater Reservoir in Spring Valley, Calif., characterize various pollutants in urban runoff. The Sweetwater project also involved the characterization and evaluation of the Sweetwater Authority Urban Runoff Diversion System, which had been constructed to protect the Sweetwater reservoir and drinking water supplies. Pankratz is now involved in an assessment of the fate of urban runoff pollutants in simulated wetland microcosms. "The major goals of this Sweetwater greenhouse project are to determine the most important environmental compartments involved in the sequestration of the pollutants, ultimately in order to develop best-management practices for maintaining and constructing wetlands to treat urban runoff and improve water quality," she says. The findings will also be used to help protect drinking water sources and aquatic ecosystems. "Urban runoff issues are a major hurdle to be overcome in addressing non-point source pollution in watersheds," explains Pankratz, who is working for the U.S. Army Corps of Engineers, Regulatory Branch while completing her doctoral studies. "The Sweetwater greenhouse project is just one small step forward in investigating a cost-effective and semi-natural means of treating urban runoff."

## Fred Gerringer

More than 1 billion people throughout the world lack safe drinking water and basic sanitation. Gerringer, a doctoral student in the ESE program working with Dr. Richard Ambrose, hopes to contribute to alleviating the problem through water treatment research. "As my education and career progress, my goal will be to help society maintain the balance between economic prosperity, access to clean water, and a healthy environment," he says. Gerringer's dissertation research involves water treatment technologies that may be used to desalinate Colorado River water diverted to Southern California. "This crucial source of water carries millions of tons of salt into the region each year," Gerringer explains. "Much of this salt accumulates in the soil and leaches into the ground during irrigation, threatening agricultural productivity and aquifers used for drinking water." One approach to this issue is to separate salts from the water using reverse osmosis (RO) membrane desalination, which can achieve removals greater than 95%. But the water must be pre-treated to remove particulates, microorganisms, and other constituents that can impair RO desalination. Gerringer's research compares potential pre-treatment processes that could be used to optimize RO membrane performance.

## Suzan Given

As a requirement of the ESE program, Given is conducting her internship at the County of Orange, Watershed and Coastal Resources Division, where she has been working on various projects related to implementation of national pollution discharge elimination system permit requirements. Given sees the Clean Water Act, which mandates the requirements, as "a vehicle to improve not only water quality, but also the quality of life for the public." She recently co-authored a paper with her adviser, Dr. Linwood Pendleton, in which she modeled health impacts from bathing in water polluted with fecal indicator bacteria. "The most important accomplishment of the publication of this paper was getting people to think about and discuss water quality issues," Given says. "It also helped to make possible the L.A. Regional Water Board's decision to protect beaches by putting teeth in the storm water permit for Los Angeles County." Given was asked to present the paper at a conference on Sustainable Management of Coastal Recreational Resources in Malta. She will soon begin her dissertation, which she hopes will lead toward better understanding of the bacterial/water pollution problem at Los Angeles and Orange County beaches as a way to better protect the beach-going public.

## Steven Lee

An aquatic ecologist with diverse interests and experiences in marine and freshwater research, Lee's investigations have led him to far reaches of the globe to study intertidal and subtidal community ecology in temperate and tropical systems. He came to the school in 1999 to work as a staff researcher with Dr. Richard Ambrose, professor of environmental health sciences (EHS). Since then, Lee has managed numerous research studies involving long-term ecological monitoring of the rocky intertidal, coastal wetland restoration, ecological/hydrological monitoring of stream/riverine systems, and the assessment of wetland regulatory programs. In 2003, Lee entered the EHS Ph.D. program. For his dissertation, he is investigating whether wetland mitigation projects, required as compensation for affected wetlands, have been successful in meeting the goals of state and federal regulations, and whether the national goal of "no net loss of remaining wetlands" is being achieved. He has produced two lengthy reports on the topic, and believes his results are having an early impact on the regulatory practices of both state and federal agencies. Following his doctorate, Lee plans to continue his pursuits in the ecology and environmental management of California's coastal aquatic ecosystems through some combination of academic, nonprofit, and consulting work.

**Students of Drs. Mel Suffet and Richard Ambrose study ways to optimize an urban runoff diversion system designed to minimize pollution at Sweetwater Reservoir, which supplies drinking water for areas near San Diego.**

health," he explains. One of Ambrose's current research directions focuses on how degraded systems can be restored back to health.

In addition to his interest in ensuring that the aquatic environment for animals and plants is a healthy one, Ambrose's research is documenting the benefits that healthy ecosystems provide to society. It's an area of research that has gained momentum among ecologists in recent years. "If we lived in Louisiana and people were going out and trapping fur-bearing animals or catching fish from the wetlands, people would appreciate that the wetlands were supplying goods to them, and they would see a value," Ambrose says. "But in areas like Southern California, where not that many people are getting goods out of wetlands or other habitats, it becomes more important to describe the benefits."

Among them are reduced flooding – wetlands can hold water and release it slowly. They can provide a habitat for birds and other wildlife. And they appear to have a protective effect on water quality in ways that Ambrose is attempting to better understand. In more than one ongoing study, Ambrose and colleagues are looking into the extent of this effect, and whether restoring the health of wetlands could improve water quality. Under the federal Clean Water Act, developments that are going to affect streams need to mitigate the impacts. Ambrose recently completed a study looking at 129 mitigation projects throughout California to determine whether the developers were compliant with the permits, and, moreover, whether the outcomes were naturally functioning wetlands with adequately protected water quality. Preliminary findings suggest that in the latter two areas, the developers are falling short. Ambrose and colleagues issued a final report to the state Water Resources Control Board, and are working with the board on implementing the recommendations.

In some cases, wetlands may be able to act as cleansers. "We've known for a long time that certain wetlands can clean up the water by removing pollutants, potentially including bacteria," Ambrose says. "But there has been little work done on whether that is the case for salt marshes – coastal wetlands that are tidal." That information is of particular interest in Southern California, where wetlands were once a significant part of the landscape. "At one time, every major river went through a wetland before it went into the ocean, and the plants that lived in those wetlands would have been removing the contaminants," Ambrose says. "But now that we've eliminated approximately 90% of all wetlands, the

question is whether those that are left are doing anything to remove contaminants."

Ambrose is specifically researching the impact of wetlands on so-called fecal indicator bacteria going into the ocean. Fecal indicator bacteria are used as indicators of contamination by human sewage, and have been associated with human health risks. The study was prompted by recent findings that in one area of Orange County, Calif., more fecal indicator bacteria were going into the ocean after the water went through a wetland than had gone into the wetland. "It looked like wetlands were actually producing these bacteria, and degrading water quality in the ocean," Ambrose says. Given that hundreds of millions of dollars are being spent trying to restore wetlands along the coast, the finding was especially troubling. Ambrose's team is currently doing a more extensive study involving four wetlands up and down the coast, with preliminary results suggesting that if anything, the wetlands are reducing the bacteria.

Water pollution typically falls under two classifications. Point source pollutants are what comes out of a pipe, whether from a water treatment plant or an industrial facility, and goes into a stream or ocean. These discharges are regulated by federal, state and local laws. Nonpoint source pollutants are less traceable – they come from a wide range of sources, from driveways and streets to the storm-drain system. "Since the Clean Water Act took effect, we've done a good job addressing the point sources – the pollution that comes out of pipes is significantly lower than it was 30 years ago," says Eric Stein (D.Env. '95), who heads the Watershed Department of the Southern California Coastal Water Research Project (SCCWRP). "But we've been much less effective at dealing with the nonpoint source pollution because it's much harder than putting a control measure at the end of a pipe or improving a treatment process."

SCCWRP is a joint-powers agency formed by several government entities that sought to pool resources and knowledge to learn more about the marine environment. In his position, Stein oversees a variety of projects related to storm water and mass emissions monitoring, watershed and water quality model development, and assessment of wetlands and other aquatic resources.

He notes that there are technical measures that could be taken to reduce nonpoint source pollution, but their cost is often considered prohibitive. "It's a combination of needing better technologies – ones that are cheaper and easier to implement – and appealing to the public on the amount of resources people want to put into solving this problem," Stein says. A considerable body of research indicates that the easiest way to solve the problem would be to reduce the amount of pollution that's generated. "That involves changing people's behaviors – how they fertilize their lawns and clean their yards and what types of products they use in their homes," Stein notes. "It's a more cost-effective, long-term solution, but much more difficult to implement."

As executive director of the Santa Monica Bay Restoration Commission, Shelley Luce (D.Env. '03) is among those who make the case that the Santa Monica Bay is vital to the regional economy, local ecology, and collective well-being of the community. The commission brings together a diverse group of stakeholders to work toward the goal of pollution prevention and restoration programs.

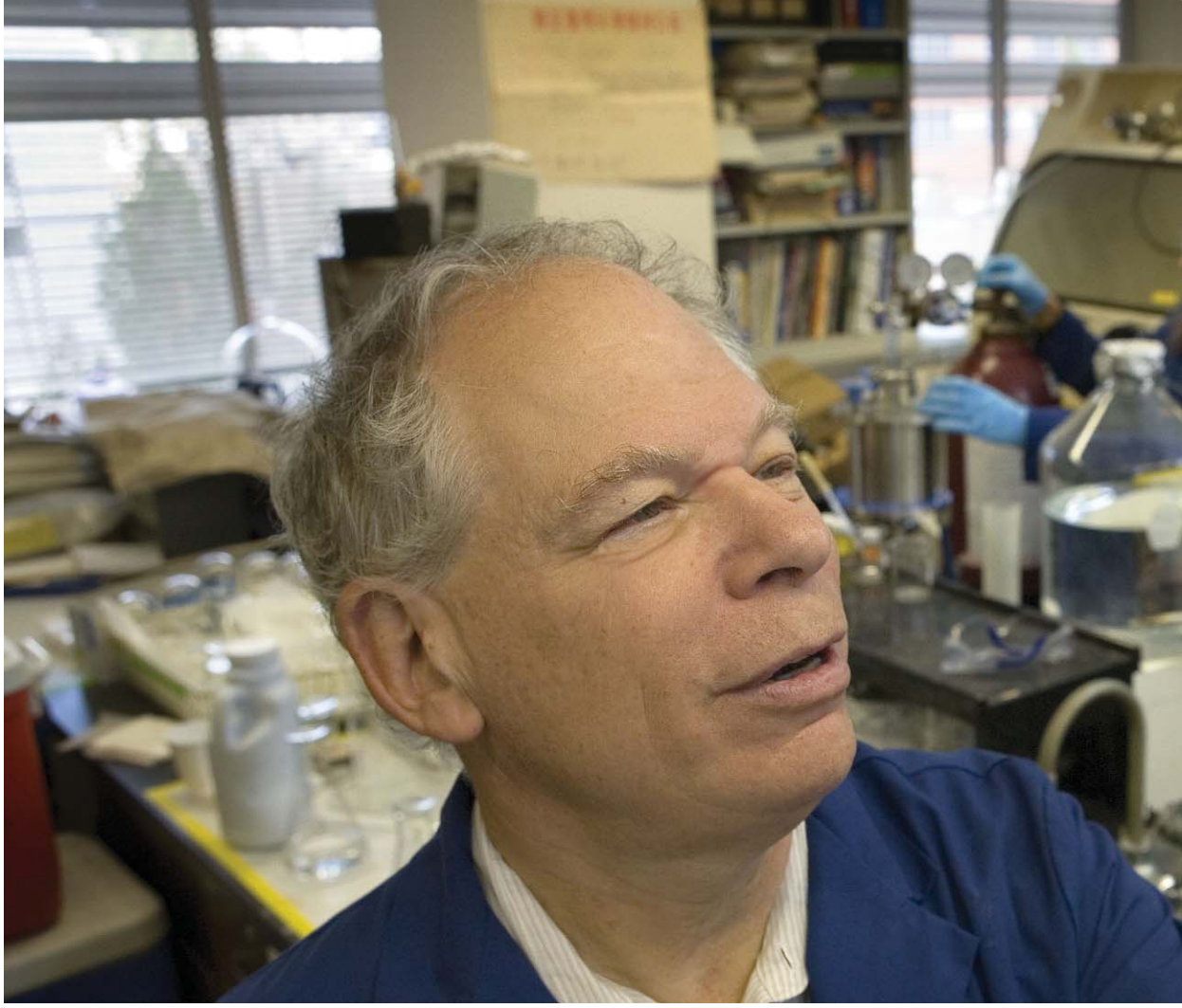
"The beaches and ocean of Los Angeles are a huge tourist attraction, with billions of dollars spent each year within a few miles of the coast on parking, eating, hotels and shopping," Luce says. "There is a major recreational fishing industry, along with scuba diving and surfing, that all contribute a great deal to our economy. And if people who swim, surf or scuba dive in the bay are getting sick, that has economic impacts as well. The bay provides food for thousands of subsistence fishers who are affected when the fish they catch are not healthful to eat. And the diversity of life in the bay is enormous."

The Santa Monica Bay is undoubtedly cleaner than it was 20 years ago, she says, but many problems remain, including DDT on the ocean floor, which contaminates fish that people eat as well as moving through the food chain to contaminate marine mammals; and sewage effluent that contains both hormones and chemicals that mimic hormones, leading to reproductive problems along the food chain.

Storm water in the region was recently addressed at the policy level with the establishment of total maximum daily loads (TMDLs), which sets a cap on aggregate bacterial levels in the coastal waters. Storm water pollution occurs when rain picks up pollutants on the land surface and transports them through the storm drainage system and into the rivers, streams, and coastal waters. When

"These issues don't get solved overnight, as much as we would like them to be. You have to stay with them, and you have to use creativity in coming up with solutions. Solving complex environmental problems is not a one-size-fits-all approach. Whether you need a legislative remedy, an engineering remedy or an educational remedy, you have to have the ability to be successful in all arenas."

— Mark Gold (D.Env. '94)



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— Dr. Mel Suffet

the federal Clean Water Act was amended in 1987, it required controls in urban areas to reduce pollution transported by storm water. Xavier Swamikannu, D.Env. '94, has led the effort by the California Water Quality Control Board and the Los Angeles Region to set the cleanup framework for municipalities and industries. In addition to helping to develop the TMDLs for trash, bacteria, and heavy metals in storm water discharges, Swamikannu was central to the Los Angeles board's action that amended the L.A. County Municipal Storm Water Permit to incorporate enforceable provisions to protect public health during summertime beach recreation.

"This is a long-term matter, but things are improving," says Swamikannu. "At first it was difficult to get people to understand why it is so important to clean up storm water. But once studies began to demonstrate the health impacts, the problem was better understood, and now officials are serious about reducing this form of pollution."

Pendleton's study made a strong argument that the board ultimately heeded in passing the guidelines. Publishing in the journal *Environmental Science and Technology*, he and his colleagues estimated from their data that in Los Angeles and Orange counties in the year 2000, 1.5 million people became sick as a result of swimming in bacteria-contaminated coastal waters. Using a conservative estimate, the authors concluded that annual public health costs associated with these illnesses – including gastroenteritis, skin rash, and ear, eye, and respiratory infections – are $51 million.

Pendleton's research looks at the economic impact of water quality changes, including both the costs associated with pollution of coastal waters and the economic benefits associated with cleaning them. His focus is entirely on day-use beachgoers in Los Angeles and Orange counties, who log 80 million beach visits per year. "So many cities have resisted regulation and have called storm water management procedures too expensive," Pendleton notes. "So it's important to determine the costs of not cleaning up, and how the benefits of cleanup compare to the cleanup costs."

Costs associated with polluted coastal waters include fewer people going to the beach, which represents an economic loss for businesses that cater to beachgoers as well as other businesses in the immediate area, Pendleton explains. People who pay higher housing prices to be near the beach also suffer, as do those who become sick from swimming in the polluted waters. And Pendleton invariably finds that the benefits of cleanup are greater than expected. In one

study, he estimated the annual recreational value of beach-going in California to be more than $2 billion a year. While continuing to delve further into these topics, he is increasingly focused on bringing them to the attention of policy makers. Pendleton is the lead non-market economist for the National Ocean Economics Program, which compiles studies on the economic value of coastal and ocean resources and makes the information available through an online database.

Pendleton wasn't the only person with a UCLA School of Public Health connection who testified at the Los Angeles Regional Water Quality Control Board hearing on TMDLs. Swamikannu and Gold, both alumni of the school's ESE program, also provided important input. "So many of our students and alumni are playing an important role in Southern California," Pendleton says. "Without a doubt, UCLA is the leader in the region in the water quality field."

The expertise and leadership that come out of the school will be much needed in the future, since the issues won't get any easier.

"The huge unknown is what's going to happen with global climate change," says Ambrose. "That covers every possible dimension – the quantity of water and its sources, as well as what will happen from our local rainstorms. We may have more extreme storms and more flooding, as well as more droughts. All of these will have human and ecosystem consequences that will have to be dealt with."

Gold, whose success at Heal the Bay has served as a model for other environmental advocacy organizations, believes that persistence and flexibility are two of the keys to progress. "These issues don't get solved overnight, as much as we would like them to be," he says. "You have to stay with them, and you have to use creativity in coming up with solutions. Solving complex environmental problems is not a one-size-fits-all approach. Whether you need a legislative remedy, an engineering remedy or an educational remedy, you have to have the ability to be successful in all arenas."

## Ryan Vaughn

Vaughn, a doctoral student in the Department of Environmental Health Sciences program, is working with Dr. Linwood Pendleton on a study to assess the non-market values of recreation in the Channel Islands and Monterey Bay national marine sanctuaries. The study addresses a gap in information needed to assess the economic magnitude of private non-consumptive activities within marine sanctuaries and the ways in which marine protection affects these values. Non-consumptive recreation includes any recreation activity that does not involve removing sanctuary resources, including scuba diving, snorkeling, whale watching, bird watching, viewing other wildlife, viewing/photographing scenery, canoeing, kayaking and sailing. Study outcomes will include the first geographically organized inventory of private non-consumptive users and values, insight into how biological and physical attributes influence user behavior and values, and the economic impacts associated with these users in terms of local expenditures and social welfare. Vaughn is interested in investigating the consequences of the spatial distribution of environmental resources on the practice of economic valuation, and hopes to develop and interpret an econometric modeling technique that takes into account individual preferences for environmental services that are spatially bundled, as well as latent effects that a resource's spatial location may have on its value.

## Robert Gilbert

Gilbert, a doctoral student in environmental health sciences, is using high-resolution mobile sensing to elucidate the impact of urban development on streams. "Freshwater streams are critical natural resources that have complex physical, chemical and biological processes," he says. "Urban development degrades these systems, reducing their ability to perform human services such as water retention and chemical processing." One effect of urbanization is that algal biomass may reach nuisance levels. In excess, algae can be unsightly, odiferous, and harmful to aquatic stream life. "Trying to assess and reduce the urban impacts leading to nuisance algae is difficult given the complexity of these relationships," Gilbert says. The mobile sensing system is part of a multi-method approach to characterizing these complex relationships. The technology, developed at UCLA's Center of Embedded Networked Sensing, enables the determination of short-term temporal and spatial patterns of biologically important stream conditions. These patterns are determined by deploying the technology at a stream and then performing repeated autonomous scans of the stream reach with a payload of water quality sensors. For his dissertation, Gilbert is attempting to combine this technology with static sensor arrays and an algal productivity bioassay to quantify physical, chemical, and algal conditions in a way that enables comparability both within and between stream reaches.