SCCWRP

2014 ANNUAL REPORT

Sediment health under evaluation

Silted bottoms of waterways hold key clues about contamination's ecosystem impacts

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

A Public Agency for Environmental Research

Welcome to the interactive version of SCCWRP's 2014 Annual Report!
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Editor
Stephen B. Weisberg, Ph.D.

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Cover Photo
"Down the Hatch," courtesy of Nicholas Paoni
A great blue heron, standing in the sediment-exposed coastal waters of San Diego County's San Elijo Lagoon Ecological Reserve during low tide, swallows a fish whole.

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Courtesy of Amec Foster Wheeler

Wading birds perch along the banks of Newport Beach's Upper Newport Bay Ecological Reserve. Portions of the sediment in Newport Bay and other Southern California coastal embayments have been contaminated, triggering far-reaching ecosystem impacts. **Page 4**

Accomplishments with journal abstracts

People

Director's Message

New format, same great science

Long-time readers of the Annual Report will notice an ambitious overhaul to SCCWRP's signature publication this year. Gone is the girth of a document that topped 600 pages last year. Instead, you will see a completely redesigned Annual Report that is intended to communicate SCCWRP's achievements to both our scientific colleagues and to the water-quality management community that forms us to provide a scientific foundation for its activities.

SCCWRP has always been much more than just a leading water-quality research organization. We enjoy a unique and invaluable connection to the management community that allows us to transition our science from research to real-world application in an expeditious, collaborative manner. However, our Annual Report format has historically been targeted primarily at our scientific colleagues, via a lengthy series of scientific journal-style articles. Our primary focus in redesigning the 2014 Annual Report is to ensure that members of our management audience, who aren't necessarily trained as scientists and who don't typically read scientific journal articles, can find content relevant to them. Environmental managers, policymakers, civic leaders and environmentally conscious citizens want to understand SCCWRP's scientific achievements just as much as scientists do, but not to the same nuanced, scientifically prodigious level.

To that end, the first portion of this year's Annual Report consists of a series of magazine-style feature articles that highlight selected aspects of SCCWRP's research, capped by an 11-page cover feature exploring why sediment quality matters to stewards of Southern California's coastal waters. This article style recognizes that our management audience is more interested in gaining an overall picture of the state of the science, with progress and accomplishments presented in ways that emphasize big-picture policy implications.

At the same time, it is equally important for SCCWRP to communicate our technical achievements to scientific partners. Thus, the second half of the Annual Report (which begins on Page 15) describes our most substantive scientific accomplishments this year and includes abstracts for the 38 peer-reviewed journal articles and technical reports co-authored by our scientists this year; we also include citation information and directions for obtaining the full text of manuscripts. The abstracts demonstrate the breadth and depth of SCCWRP's research prowess, even as we save on paper by no longer including the full text of these articles. Our abstracts-only approach also reflects a shift in the journal publication timetable. Whereas a decade ago it was important to include full scientific articles in the Annual Report because an author might wait two years after journal acceptance to see an article published, this time lag has been dramatically curtailed via many journals' commitment to online-first publication. Most of the abstracts featured in this Annual Report have already been published as articles in journals, and thus there is no need for us to reprint them.

SCCWRP recognizes that the changes to this year's Annual Report represent a significant departure from established practice. I am hopeful you'll find the document to be effective at the dual goal of reaching our management-level audience, while still serving as a valuable reference document for our technical audience. I look forward to your feedback on whether we have accomplished that objective.

Stephen B. Weisberg, Ph.D.
Executive Director

Dissecting SCCWRP's cell phone microscope

To monitor the health of aquatic ecosystems, environmental scientists routinely wade through streams scooping up samples of algae, diatoms and tiny invertebrates. Each sample is preserved on site and then transported back to a lab for identification and analysis.

Not only is the process cumbersome, but these specimens, especially algae, tend to degrade quickly in preservative fluids, making them harder for a taxonomist to identify later.

SCCWRP is pioneering a promising solution with bioengineering researchers at the University of California, Berkeley: A portable microscope that gives researchers a way to examine specimens in the field while they're still fresh, and to take photos of the specimens with their own cell phone.

Pilot study

SCCWRP is piloting a study to assess whether a smartphone attached to a portable, handheld microscope can capture specimen images of comparable quality to a lab microscope's – and with acceptable reliability and reproducibility.

Known as the CellScope, the 1½-pound microscope consists of a mostly plastic device created with a 3-D printer. A smartphone that inserts into a custom-designed slot serves as both the microscope viewfinder and an image-capturing tool.

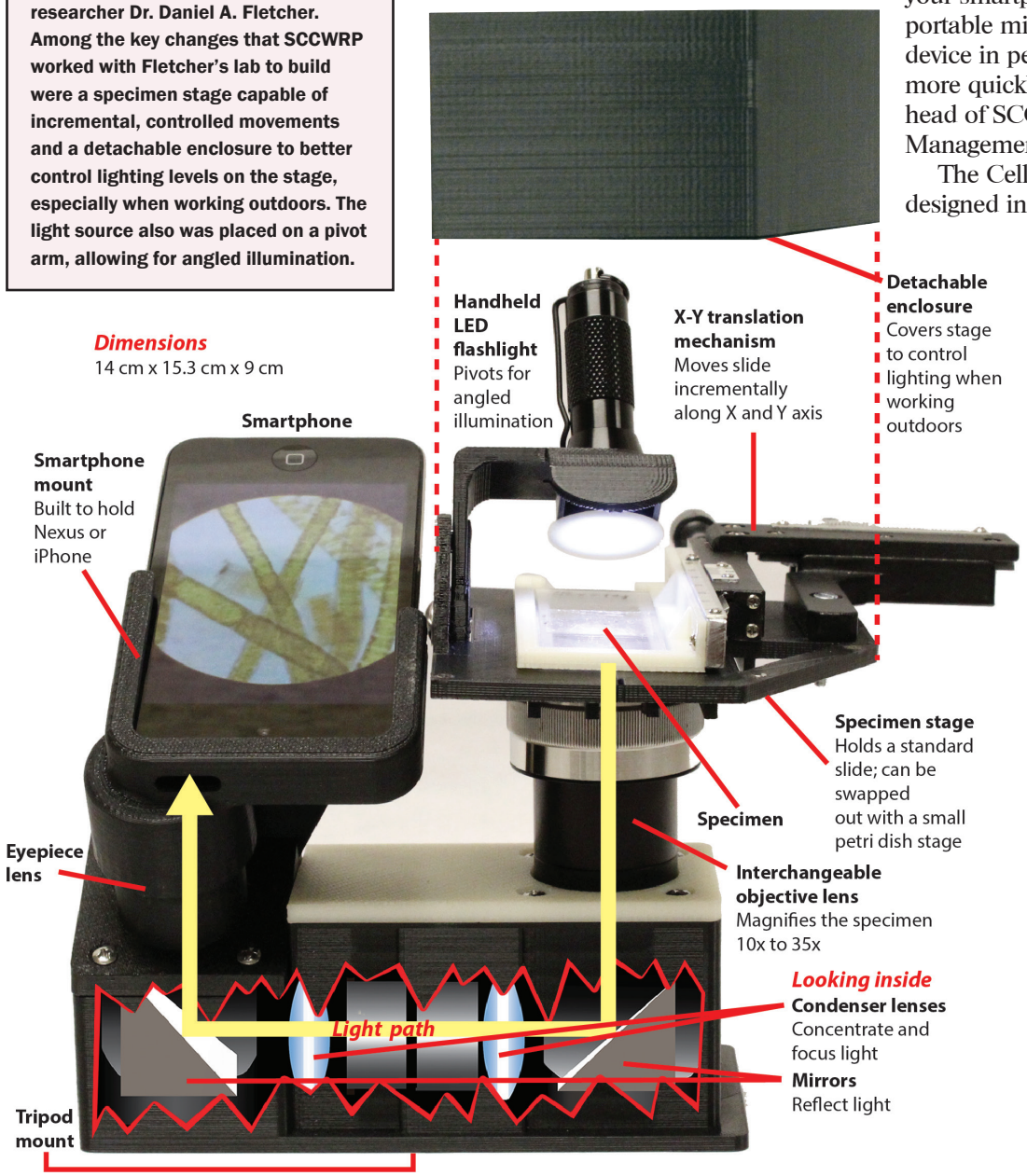
"You're not going to take $2,000 and $3,000 microscopes out into the field, but if you can use your smartphone attached to a $500 portable microscope, you can put that device in people's hands and get data more quickly," said Dr. Steve Steinberg, head of SCCWRP's Information Management & Analysis Department.

The CellScope was originally designed in 2008 for use in diagnostic medical applications in developing countries, where there aren't enough on-site physicians to diagnose diseases like sickle cell anemia.

SCCWRP teamed up with the Berkeley lab in 2013 to adapt the microscope for environmental monitoring; testing will wrap up in 2015.

Adapting the CellScope

The CellScope was designed in 2008 by UC Berkeley bioengineering researcher Dr. Daniel A. Fletcher. Among the key changes that SCCWRP worked with Fletcher's lab to build were a specimen stage capable of incremental, controlled movements and a detachable enclosure to better control lighting levels on the stage, especially when working outdoors. The light source also was placed on a pivot arm, allowing for angled illumination.



Promising future

The CellScope could pave the way for rapid, in-field analysis of aquatic organisms. Field technicians could photograph freshly collected samples, then trasmit the images in real time to a taxonomy expert for confirmation and follow-up. SCCWRP also could cut down on the workload of taxonomists by making the process of identifying specimens automated, using the technology that's behind facial recognition software.

Taking surfer vitals

SCCWRP tracks the health of SoCal's ocean-loving denizens to understand how rainfall impacts ocean water quality, in the first U.S. study of its kind.

Scientists know that Southern California beachgoers are at relatively low risk of getting sick when entering the ocean – as long as they follow all posted signs and go between April and October. That's because water quality is routinely monitored during these peak sunbathing months, and scientists have comprehensively documented the thresholds at which water contamination levels begin to impact human health.

But during Southern California's colder months, an intermittent weather phenomenon – rain – dramatically impacts the composition of coastal ocean waters.

Rain water that flows through the region's sprawling storm drainage system picks up a variety of contaminants from across thousands of square miles of highly engineered landscapes – contaminants that are never treated or removed as they rush toward the coastline.

Scientists have little data on how this wet weather impacts ocean water quality, and public health officials have responded by erring on the side of caution: They issue blanket advisories after every rainfall that warn people not to enter the ocean for three days.

Still, this stopgap measure hasn't resolved the underlying epidemiological issue: Are people who enter coastal ocean waters after heavy rains getting sick from land-based runoff?

Enter surfers, the adventuresome, ocean-loving denizens who don't let a little damp weather get in the way of riding Southern California's famous waves.

Ocean Beach, one of two surfing hotspots in San Diego where SCCWRP recruited volunteers for its Surfer Health Study.

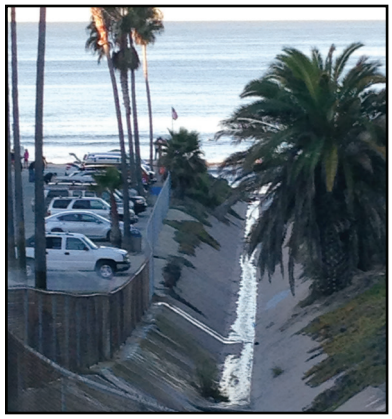
In a first-of-its-kind study, SCCWRP is seeking to find out the extent to which the health of local surfers is affected by contaminated ocean water during Southern California's rainy winter season. The University of California, Berkeley and the San Clemente-based Surfrider Foundation are study partners.

"No one has been able to definitively answer the question of whether coastal beach water is more harmful to humans following a storm event," said lead study author Ken Schiff, SCCWRP's deputy director. "We're

Surfing after rainfall

Surfers are among the few beachgoers who brave Southern California's chilly waters following rainy weather. Although public health officials issue a blanket advisory after every rainfall urging people not to enter coastal waters, many surfers are drawn to the big waves that storms typically bring.

Surfers paddle away from shore during a sunny winter morning at Ocean Beach in San Diego, just one day after a torrential downpour. Scientists want to know the extent to which rainfall runoff in coastal ocean waters is making ocean bathers sick.



Tourmaline Surfing Park in San Diego, at the receiving end of a storm drain channel, gets deluged with land-based runoff following heavy rains. The goal of SCCWRP's study is to assess whether runoff is dangerous to humans during and immediately after rainfall.

SCCWRP field technicians wade into the water at Ocean Beach to collect samples that will be tested for bacteria and viruses. Stormy weather from earlier in the day leaves behind a rainbow in the distance.

going to quantify that risk and compare it to what the empirical data tell us."

Although scientists know that wet weather in Southern California is sending a variety of contaminants into coastal ocean waters, it isn't clear if this runoff is triggering dangerous spikes in disease-causing bacteria and viruses.

For the four-month Surfer Health Study, which began in December 2014, hundreds of local surfers who frequent two popular San Diego beaches – Ocean Beach at the mouth of the San Diego River, and Tourmaline Surfing Park a few miles north – were tracked for how they were feeling each day and how often they entered the ocean. Both beaches are popular surfing spots and at the receiving end of storm drain channels.

At the end of each week, study participants were asked to use a custom-designed app on their smartphone to log any illness symptoms they experienced and when and for how long they went into the water. For every four weekly surveys completed, volunteers received $20 gift certificates to the surfing retailer Swell.com, a study partner.

"Surfers are ideal study participants because about one in three of them will go into the water right after a rain event; some will even go in while it's raining," Schiff said.

While the epidemiology study was being conducted, researchers also tracked the levels of bacteria and viruses in the water at the two beaches on a daily basis; these data were then correlated with the epidemiological data.

The main question researchers want to know is whether it's more dangerous to enter Southern California's coastal waters in the three days following rain than at other times of the year.

Schiff said that if rainfall is elevating pathogens in coastal waters to hazardous levels, water-quality managers will know they need to continue their efforts to more effectively treat stormwater discharge and to stop the biggest sources of pathogen-laden water from entering storm drains.

Conversely, if the study finds no appreciable impacts from rainfall, regulators and water-quality managers will want to re-evaluate the very high price tag of the strategies they're taking to remediate and clean up stormwater discharge, Schiff said.

Results of the study are expected to be published in mid-2016.

Did you know?

Study participants were considered to have surfed in "wet weather" conditions if they entered the ocean within three days of at least one-tenth of an inch of rainfall.

SEDIMENT HEALTH UNDER EVALUATION

California has spent decades working to set quality standards for the silted bottoms of its coastal waters. SCCWRP has played a pivotal role.

Courtesy of Amec Foster Wheeler

A brown pelican perches on a dock in San Diego Bay.

Fish were peppered with skin lesions and fin rot, expansive kelp beds were shrinking, and the populations of endangered bird species like the bald eagle and brown pelican were plummeting. Pollution in Southern California's coastal waters had reached historic levels by the 1970s, and marine environmental managers could do little to reverse the tide. They simply didn't have the rigorous body of scientific work needed to identify solutions – or to justify paying for them.

The federal Clean Water Act of 1972 and corresponding state laws provided an initial focus for management efforts – that is, cleaning up the highly polluted coastal water itself – but as treatment plans were rolled out, the health of marine life did not always improve in lock step.

Certainly, marine communities began rebounding from catastrophic conditions, and the most alarming signs such as fish tumors gradually faded to background levels.

But marine organisms in Southern California's coastal waters continued to be plagued by high concentrations of toxic chemicals, including the now-banned pesticide DDT, and scientists continued to find evidence of reproductive failure and nest abandonment in brown pelicans and other seabirds.

SCCWRP researchers collect sediment core samples from the silted bottom of Newport Bay in Newport Beach.

Courtesy of TNC/IfAME/MARE

A predatory sea slug, center, rests on a soft surface layer of sediment, surrounded by polychaete worms. This sediment layer, just inches deep, supports a variety of bottom-dwelling, or benthic, life forms that comprise the base of the marine food web.

There was another piece to this puzzle.

Scientists had long hypothesized that high concentrations of contaminants would be found on the sea floor. As they broadened the focus of their water-quality monitoring efforts to include sediment contamination, they discovered just how right they were.

"At the beginning, there was a lot of uncertainty and lack of knowledge, but we knew that sediment would be an important sink for certain chemicals and a long-term exposure route for organisms," said toxicologist Steve Bay, a leading expert on sediment quality who heads SCCWRP's Toxicology Department. "These chemicals were persistent and could get transported long distances."

Over time, stewards of Southern California's coastal waters have come to view sediment quality as a sentinel indicator of marine health, on par with water quality itself. Pollutants discharged into coastal waters tend to stick to particles suspended in the water and settle to the bottom, concentrating contaminants at far higher levels than in the water column itself – and creating a potentially toxic presence for generations to come.

Removing all contaminated sediment from coastal waters would be a prohibitively costly and unrealistic endeavor. Decades of pollutants flushed down drains and discharged from watersheds have created widespread sediment contamination across hundreds of square miles along California's coastline. The problem is particularly acute in bays and estuaries, where slower-flowing waters promote settling of contaminant-laden particles.

Still, contamination in the seabed floor cannot be ignored: Scientists know that contaminants in sediment move through the food web and eventually reach humans.

Consequently, state and federal regulators have developed a measured, balanced approach to dealing with sediment contamination – one that utilizes multiple scientific disciplines and takes into account the unique characteristics of different bodies of water.

"We should not require an expensive cleanup until we really understand how much benefit the cleanup will achieve," said engineering geologist Chris Beegan, who oversees sediment quality initiatives for the California State Water Resources Control Board. "So what can we do? We work together to develop feasible plans."

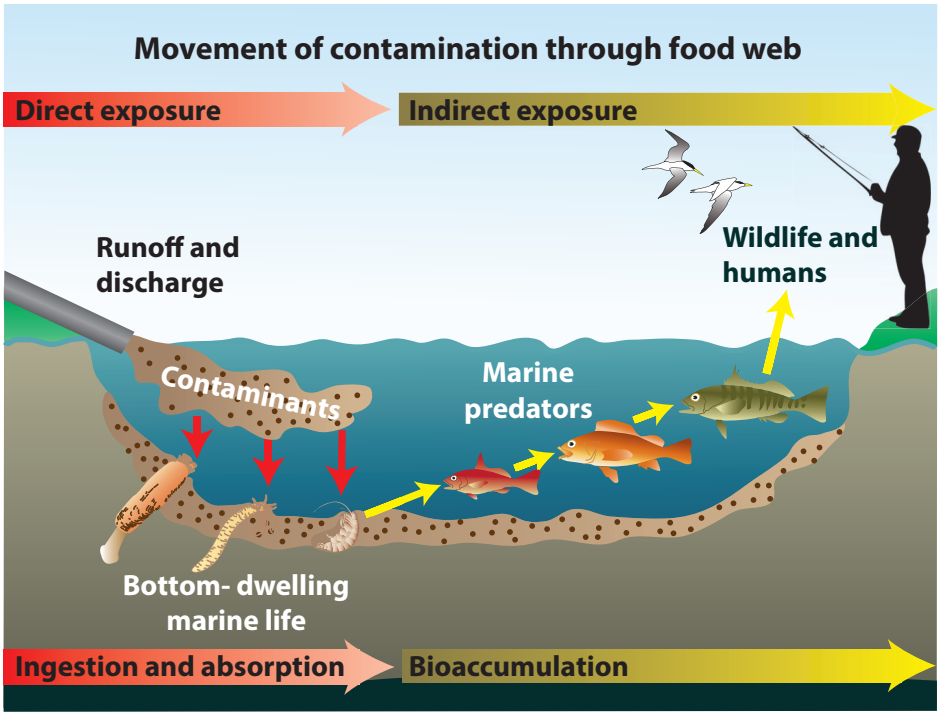
What causes sediment contamination?

A variety of human activities have contributed to sediment contamination in Southern California. Contamination can come from disparate sources such as:

- **Shipbuilding/boat repair**
- **Oil drilling and extraction**
- **Aquatic recreation activities**
- **Pesticide use**
- **Cars and trucks**
- **Air pollution**
- **Scrapyards and recycling facilities**
- **Petroleum storage and transport**
- **Chemical manufacturing**

Courtesy of Amec Foster Wheeler

Field technicians for the Southern California Bight Regional Monitoring Program collect sediment grab samples in San Diego Bay, part of an effort to track the impacts of sediment contaminants on bottom-dwelling marine life.



Some of the contamination that enters coastal waters via rainfall runoff and discharge settles in sediment, where it gets ingested and absorbed by bottom-dwelling marine life. As these organisms are consumed by predators, contaminants build up – or bioaccumulate – in each successive predator that eats its prey. This contamination eventually reaches humans.

Sediment affects entire food web

Humans and most wildlife will never come into direct, prolonged contact with the sea floor, but organisms including burrowing worms, crustaceans and clams spend their entire lives in and on the surface sediment layer.

Typically just a few inches deep and made up of sand, silt, clay, and organic matter, this narrow zone teems with life forms comprising the foundation of marine food webs – webs that extend all the way to humans.

Scientists have found that as these organisms take up contaminants from sediment, the contaminants are transferred to the predators that consume them.

Furthermore, the health impacts are exponentially multiplied as contaminants build up – or bioaccumulate – at each successive level of the food web.

"The more steps you have, the worse it can get," said Dr. Katie Zeeman, an environmental containment specialist for the U.S. Fish and Wildlife Service in Carlsbad. "That's why we focus on monitoring for contaminants that are likely to magnify and accumulate in the food web."

Toxic chemicals like the now-banned pesticide DDT have been shown to increase 10- to 100-fold in concentration by the time they reach gulls, terns, ospreys and other seabirds at the top of the food web.

Mostly under control

Over the past few decades, strict regulations have helped environmental managers dramatically reduce sediment contamination loads from wastewater discharges. Reducing sediment contamination loads from land-based runoff, though, remains one of the biggest challenges for the environmental management community, as does legacy contamination that will pose a threat for generations into the future.

Sediment presents multifaceted challenge

As much as sediment has provided an important new focus for water-quality research, it also has come with myriad challenges. Water quality historically has been measured with relatively simple, chemistry-based analyses; the same is not true of sediment. Scientists found that evaluating sediment quality requires taking into account three main sources of variability:

» **Bioavailability:** Although chemical tests can measure precisely how contaminated a layer of sediment is,

Like many Southern California embayments, Upper Newport Bay Ecological Reserve in Newport Beach is at the receiving end of a storm drain system that carries a variety of land-based pollutants to coastal waters. Human activities ranging from manufacturing to agriculture to home pesticide use all contribute to sediment contamination.

the animals that burrow in it are not necessarily exposed to its full toxicity. Indeed, some contaminants can be stuck so tightly – or even chemically bound – to sediment that the surrounding marine community is not impacted by them, making it difficult to accurately predict toxic effects from sediment chemistry data. Scientists call this concept the biological availability, or bioavailability, of sediment contaminants. Bioavailability varies from site to site and is strongly influenced by sediment characteristics like grain size and amount or type of organic matter.

» **Multiple uptake routes:** Scientists cannot focus solely on understanding how contaminants cross the water-blood barrier of an organism's gills, because the gill isn't necessarily the only – or even primary – method of contact with contaminants. Indeed, many bottom-dwellers get a contaminant dose when they ingest contaminant-laden sediment particles while feeding.

» **Complex chemical mixtures:** Sediment contamination rarely consists of just one chemical of concern; it is typically a "soup" of toxic metals, pesticides, petroleum compounds and other industrial chemicals, all with differing potentials to impact marine life. In some cases, it's not possible to trace impacts back to an individual contaminant, as impacts are the combined result of multiple chemicals. Also, scientists don't fully understand how chemicals interact with one another as a mixture, creating knowledge gaps about the cause of impaired sediment quality and how to effectively remediate impacts.

Despite these challenges, monitoring the quality of sediment has allowed scientists to amass far more reliable, consistent data about the health of marine ecosystems than by measuring water quality in the constantly churning sea.

"Sediment was a turning point for our research," Bay said. "Sediment doesn't change on an hourly or even a daily basis, which has allowed us to integrate contaminant exposure over time."

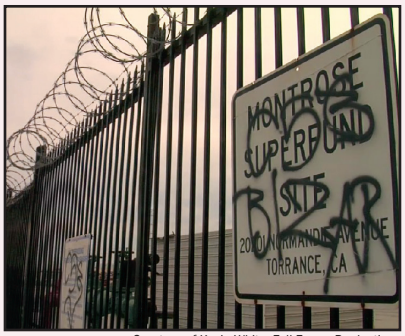
From the outset, SCCWRP has been a national leader in efforts to measure and track contamination levels in sediment.

In 1977, just as U.S. marine researchers were beginning to study seabed sediment in earnest, SCCWRP piloted a landmark study to evaluate sediment quality at more than 70 offshore locations spanning the Southern California Bight, from Point Conception in Santa Barbara County to the U.S.-Mexico border.

Samples were collected at a depth

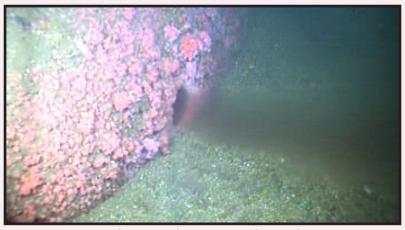
Primary culprits in Southern California's legacy of sediment contamination

Much of the contamination in Southern California's seabed sediment is from activities that predate strict environmental regulations enacted in the early 1970s. This contamination, which sits largely undisturbed on the bottom of shallow coastal waters, is continuing to exert toxic effects on marine ecosystems.



Courtesy of Kevin White, Full Frame Productions

Industrial discharges were a leading contributor to sediment-quality impairment prior to the 1970s. One of Southern California's biggest legacy polluters, the now-demolished Montrose Chemical Corporation, left, near Torrance is believed to have discharged as much as 1,700 tons of the now-banned pesticide DDT (dichlorodiphenyltrichloroethane) onto the Palos Verdes Shelf via a wastewater outfall about a mile offshore. From the late 1950s to the early 1970s, DDT and its derivatives blanketed an area that stretches more than 9 miles along Los Angeles County's coastline. The Palos Verdes Shelf remains classified as a federal "superfund" site to this day, largely because of high DDT concentrations in sediment. DDT-laden runoff from Montrose also traveled through storm drains and ended up at the bottom of the Los Angeles and Long Beach harbors.


Courtesy of Los Angeles County Sanitation Districts

Wastewater outfalls that discharge treated sewage into the ocean were once a major source of sediment contamination. Beginning in the 1950s, environmental managers responded by moving outfalls farther offshore, away from human aquatic activities and sensitive marine habitats; they also began treating wastewater more intensively prior to discharge and more tightly controlling industrial contaminant sources. This multi-pronged strategy dramatically reduced contaminant levels in wastewater discharge, by as much as 97%. Above, a circular outlet along an anenome-covered outfall releases a plume of effluent nearly two miles off Los Angeles County's coast; the plume appears a different color because of its differing salinity.

Rainfall runoff that picks up contaminants from a wide variety of human activities – from manufacturing to agriculture – flows through waterways and eventually reaches coastal embayments. At left, this view facing south at the mouth of the Los Angeles River in Long Beach shows murky, particle-laden water accumulating in the harbor area near the Queen Mary following heavy rains. When the river water meets slower-flowing embayment waters, chemical contaminants in the water tend to stick to sediment particles and settle to the bottom, where they can create a toxic coastal presence for generations to come. Preventing these pollutants from entering Southern California's waterways remains a complex and difficult problem to solve.

Milestones in sediment quality assessment

1971: The U.S. Environmental Protection Agency issues sediment quality guidelines for dredged sediment that establish maximum allowable concentrations for seven specific chemicals. Sediment is deemed too contaminated for open-water disposal if the concentration of any of the seven chemical exceeds respective thresholds.

1985: A new approach called the sediment quality triad that relies on three main tests – chemistry, toxicity and biology – is used for the first time to evaluate sediment quality in Puget Sound, Washington. Previously, only chemistry and toxicology tests were used.

1989: The California Legislature instructs state water officials to develop sediment quality objectives to protect bays and estuaries. The workplan that gets developed, however, focuses primarily on identifying toxic hot spots.

2001: California is ordered by a Sacramento court to adopt sediment quality objectives, in response to a lawsuit that accuses the State Water Board of failing to take this action. The court order leads to the development of California's modern-day Sediment Quality Objectives.

2009: The California State Water Resources Control Board formally adopts the Sediment Quality Objectives program to regulate sediment quality in bays and estuaries. SCCWRP and its collaborators developed the scientific foundation for the program, which is the first of its kind in the nation.

of 60 meters, the point where most of Southern California's water sanitation agencies were discharging their treated wastewater.

Scientists found sediment contamination levels notably higher in the areas closest to the discharge sites, affirming the potential for human-caused damage to California's marine ecosystem.

Dredging prompts first sediment standards

Concerns about sediment quality in U.S. waterways first came onto the national radar in the late 1960s, as environmentalists and scientists began voicing alarm about dredging in harbors and estuaries.

Although dredging was necessary to maintain navigable depths for shipping routes, environmentalists warned that disposing contaminated sediment elsewhere could have serious, long-term repercussions on the marine ecosystem where the disposal took place.

In the early 1970s, federal regulators began developing initial standards related to the disposal of dredged sediment. Before any sediment could be removed, dredgers were required to assess the concentrations of seven specific chemicals, according to 1971 rules issued by the U.S. Environmental Protection Agency. If any of the seven chemicals exceeded a maximum threshold, the material was deemed too polluted for open-water disposal.

Although limited and rudimentary by today's standards, these initial, chemistry-based standards paved the way for increasingly sophisticated and varied assessment methods.

By the 1990s, federal officials had created detailed sediment quality guidelines that explained how to measure contaminant levels through chemistry-based approaches and to link the results to toxicity effects observed in the lab.

Developed primarily by the EPA and the National Oceanic and Atmospheric Administration, these guidelines have been refined, vetted and adopted over the years, and today they're being used across the globe in a variety of settings and contexts.

California pushes ahead with triad

While federal officials focused on developing sediment quality guidelines based on chemistry and toxicology data, California was an early pioneer in integrating a third assessment method into the mix: measuring the health of the marine organisms living in the sediment itself.

Scientists found that this so-called Sediment Quality Triad approach – first tested in Washington's Puget Sound in 1985 – provided more accurate, replicable results than chemistry and toxicity alone. The triad approach considers three lines of evidence:

» **Chemistry:** Concentrations of contaminants in a sediment sample

» **Toxicity:** Survival, growth and reproduction rates of organisms when exposed to sediment in a lab setting

» **Biology:** Assessment of the abundance and diversity of sediment-dwelling organisms in their natural habitat

Even after ordering up these three types of tests, however, regulators and dischargers in the end relied on their best professional judgment to interpret the results. Scientists weren't able to offer a technically consistent system by which regulators could weigh each of the three lines of evidence using objective evaluation criteria.

"People were using different toxicity tests and different chemistry methods, and sometimes they'd only use chemistry or toxicity, or sometimes they'd use two lines of evidence," Beegan said. "There was no standardized process for assessing sediment quality."

SCCWRP develops triad indices

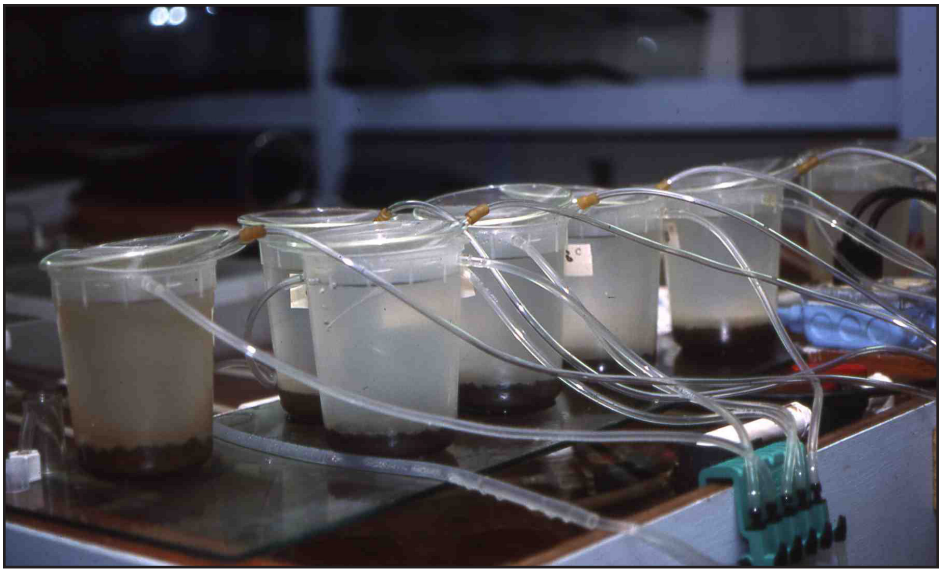
In 2003, California's State Water Board and SCCWRP embarked on

A clam, left, and a polychaete worm from a bioaccumulation experiment are sifted out of the sediment so they can be chemically analyzed. Mollusks and worms are two major components of bottom-dwelling marine communities.

an ambitious project to develop weighted indices that take much of the guesswork and professional best judgment out of the triad evaluation process.

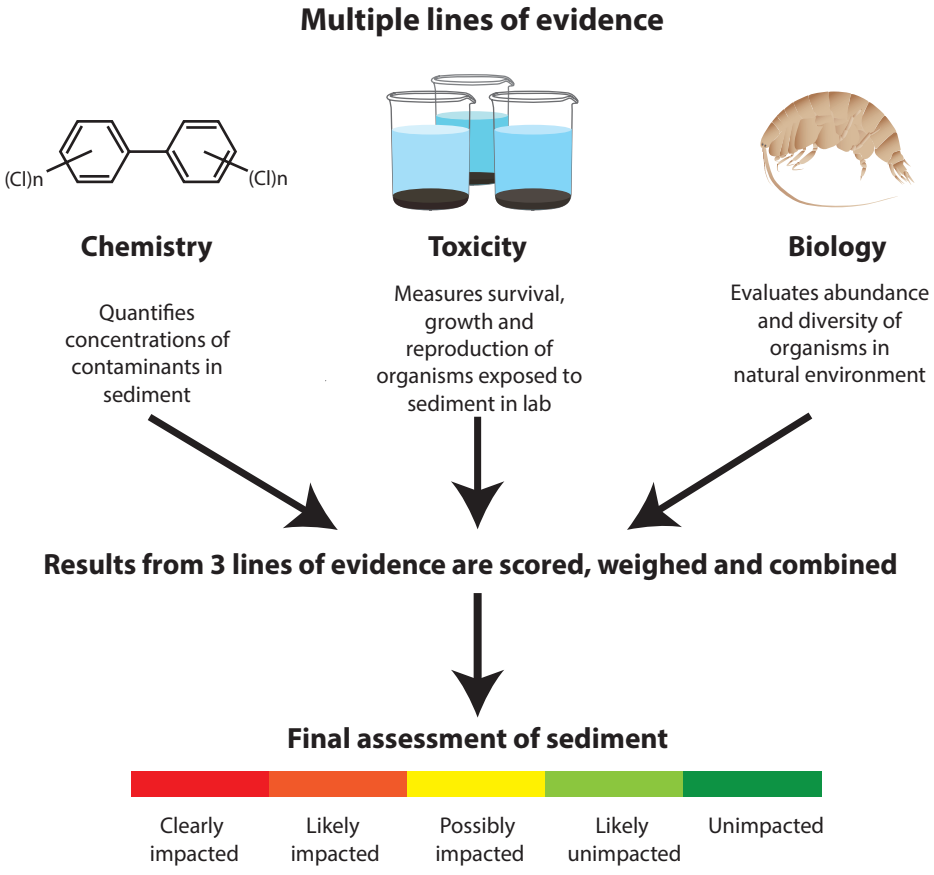
SCCWRP's assessment framework and protocols were adopted by the state six years later to regulate sediment health in bays and estuaries; the Sediment Quality Objectives program explains everything from how samples are collected and analyzed to the mathematical formulas used to interpret the data. The detailed protocols also provide technical guidelines for how agencies tasked with meeting specific objectives can most effectively achieve their goals.

Today, SCCWRP's research forms the technical foundation for sediment testing in a variety of contexts, including in the permitting process, compliance monitoring, regional surveys like the Southern California Bight Regional Monitoring Program, and regulatory programs designed to control and lower pollutant concentrations.



Bottom-dwelling marine organisms are placed inside toxicity exposure chambers filled with sediment and seawater during a SCCWRP toxicity experiment. The test organisms are exposed to the sediment for a specified time period; then, scientists measure survival, growth and reproduction rates. The attached tubing delivers air and water.

"Sediment Quality Objectives are about working with people to make sure things are implemented properly," said Beegan of the State Water Board. "SCCWRP does the science, then we use the science to inform the implementation."



California was an early pioneer in assessing sediment quality via three main lines of evidence: chemistry, toxicity and biology. In the early 2000s, SCCWRP began developing the scientific framework that explains how to score, weigh and combine data from these three lines of evidence to assess the condition of sediment.

Scientists studying higher-level food web impacts

Much work remains to help water-quality managers figure out how to monitor sediment contaminants and work toward ensuring the health of marine food webs.

During development of the state's

Limitations of each line

Why a single line of evidence isn't good enough

Chemistry

- Doesn't measure every possible contaminant
- Cannot account for contaminants that, when mixed together, have interactive effects
- Cannot gauge contaminants' bioavailability to organisms

Toxicity

- Cannot identify cause of adverse health effects
- Because tested in lab setting, may differ from field conditions

Biology

- Cannot distinguish between contaminant-related impacts vs. impacts due to oxygen deficiency, physical disturbance or excessive organic nutrients

Storm drains like this one that terminates at Newport Bay in Newport Beach, above, carry land-based contaminants to coastal waters. Some of the contamination settles in sediment, creating a long-term, toxic problem.

Contaminated seafood

Contaminants from sediment are still showing up in some of the seafood along Southern California's coast. In 2011, the California State Water Board released a study that examined contaminant levels in six sport-fish species commonly caught along a roughly 200-mile stretch of coastal waters from Ventura County to Tijuana, Mexico. The study showed that some fish continued to test positive for potentially hazardous levels of two chemicals typically found in sediment: the industrial chemical PCB (polychlorinated biphenyl) and the now-banned pesticide DDT (dichlorodiphenyltrichloroethane).

PCBs: One in three seafood samples from the study contained so much PCB that California has recommended limiting consumption of these fish to no more than two, 8-ounce servings a week, according to state consumption advisory guidelines designed to protect human health. The seafood samples with the highest PCB levels came from coastal embayments; state PCB guidelines recommend limiting consumption of these fish to no more than one serving a week.

DDTs: DDT levels in Southern California sport fish were dramatically lower than PCB levels, with none of the samples exceeding the state's DDT consumption guidelines, according to the 2011 study. Some fish species even fell below the long-term DDT target threshold of 21 parts per billion, although achieving this threshold remains a work in progress for other species, including the bottom-dwelling white croaker, whose average DDT levels clocked in at twice the target level, according to the study.

Source: California State Water Board 2011 study on contaminants in sport fish

Sediment Quality Objectives program, scientists focused on bottom-dwelling organisms that live in the sediment of California's bays and estuaries. Now, scientists are expanding the reach of this program by turning their attention to organisms higher up in the food web, including assessing risk to human health from consuming locally caught seafood.

As researchers study these higher-level organisms, however, they run into progressively more complex challenges in understanding which health impacts are caused by local sediment contamination versus by a multitude of other factors, including air pollution, migration and changes in feeding behavior.

Scientists call these higher-level impacts indirect exposure effects, and they expect to spend just as much time – if not much longer – to reach

Q&A: What does monitoring data reveal about Southern California's sediment quality?

Assessing the health of Southern California's coastal waters requires rigorous, careful sampling and amassing data sets that can be compared across both distance and time.

Since the mid 1990s, Southern California marine scientists have been able to answer key questions about the health of coastal sediment through the Southern California Bight Regional Monitoring Program, one of the most robust, comprehensive aquatic monitoring programs in the nation.

Facilitated by SCCWRP, the collaborative program provides comprehensive monitoring every five years for the Southern California Bight, a 400-mile-long region that stretches from Point Conception in Santa Barbara County to the U.S.-Mexico border. The survey includes the open ocean, embayments and the Channel Islands environs, including Catalina.

Is poor sediment quality a big problem in Southern California?

The good news is that 97% of all sediment in Southern California's 3,000 square miles of coastal waters is not considered impacted by contaminants, according to the most recently released data from the Bight '08 survey. That's not to say, however, that sediment contamination isn't widespread. Sediment contamination itself is found across an estimated 400 to 500 square miles of the region's coastal waters; it's just that not all of this contamination is considered to be impacting ecosystem health. Furthermore, impacts are much more dramatic in Southern California's bays, estuaries, ports and marinas, where 27% of sediment is deemed to be "possibly," "likely" or "clearly" impacted by contamination.

Which types of embayments are most impacted?

Although the vast majority of impacts from Southern California's contaminated sediment are found in embayments, scientists have identified dramatic differences among the four types of embayments: About 50% of estuarine zones and marinas are impacted by sediment contaminants, vs. only about 20% of open bays and ports, according to the Bight '08 survey. Also, estuaries and marinas are more likely than bays and ports to have more severe impacts from sediment contamination, according to survey data.

Are sediment contamination impacts in the Southern California Bight getting better or worse?

The extent of sediment contamination impacts has been declining in Southern California's embayments, according to survey data collected from 1998 to 2008. The extent of impacts in embayments dropped by half during this decade-long span, from 55% to 27%; the extent of embayment sediments with moderate to high toxicity dropped by two-thirds, from 36% to 11%. Also, the health of marine communities living in embayment

the same level of success they have had assessing sediment contamination impacts on bottom-dwelling marine life.

SCCWRP's focus is on developing sophisticated scientific models that predict how pollutants from sediment and other sources bioaccumulate in the food web and ultimately are ingested by humans.

SCCWRP also is developing strategies to track additional contaminants whose health impacts aren't fully understood. These so-called contaminants of emerging concern, or CECs, could be just as much of a public health threat as known pollutants, especially those that commingle with sediment. But until scientists develop the tools to effectively monitor them, environmental managers can do little to regulate them.

Benthic ecologist Dave Montagne, now retired from the Los Angeles County Sanitation Districts, said he expects to see sediment quality regulations get tighter and more expansive as science advances, just as they did during his nearly 40-year tenure with the sanitation agency.

Children and adults cast their lines off a popular fishing pier in San Pedro. Some of the most popular sport fish caught in Southern California continue to test positive for hazardous levels of contaminants believed to have originated in sediment.

The high price tag of these initatives will renew fundamental questions about how public money should be spent, he said.

"When we have all of these legacy pollutants that are going to persist for years to come, are we achieving anything by spending more money on the problem?" Montagne said.

"Inevitably, this will lead to some back and forth: Is it worth the cost? And that is a good question to ask."

sediment improved; the portion of embayments whose bottom-dwelling aquatic life was deemed moderately to highly disturbed fell from 25% to 12% over the course of the decade.

How are advances in sediment science helping water-quality managers?

The science being done by SCCWRP and its collaborators is routinely translated into improved policies and regulations. For example, after the Southern California Bight Regional Monitoring Program became one of the first in the nation to monitor the health of bottom-dwelling marine life as an indicator of sediment health, state regulators implemented a version of these protocols to protect bays and estuaries in 2009.

Also, even as California's Sediment Quality Objectives (SQO) program for bays and estuaries was being finalized, the Bight program incorporated the state standards into its 2008 monitoring study, adapting the approach for evaluating offshore habitats.

This synergistic effort produced more reliable, comparable scientific data for both the state SQO program and the Bight program. As every environmental manager knows, having better data means scientists can state their results with a higher degree of certainty, which helps managers to make better-informed policy decisions.

SCCWRP researchers use a grab sampler to collect surface sediment from the bottom of Newport Bay in Newport Beach.

Why should water-quality managers still care about sediment contamination?

The known extent of sediment contamination has been decreasing over time, but researchers have only recently begun to study many other chemicals with the potential to impact marine life and bioaccumulate through the food web.

Environmental managers are concerned about these contaminants of emerging concern, or CECs, such as pyrethroids and PBDEs (polybrominated diphenyl ethers).

Pyrethroids, commonly used in pest-control formulas, can be acutely toxic to marine life such as crustaceans because of their physiological similarities to insects; pyrethroids have been identified in a third of California embayment sediments, according to the most recently released Bight '08 program findings.

Meanwhile, PBDEs, commonly used as flame retardants, are known to bioaccumulate in fish and humans; PBDEs were found in 95% of all sediment and 100% of embayment sediment.

Scientists are continuing to track and study CECs, including in the most recent Bight survey conducted in 2013, as they work to fully understand the long-term health implications for human and marine life.

SCCWRP's contributions to sediment quality science

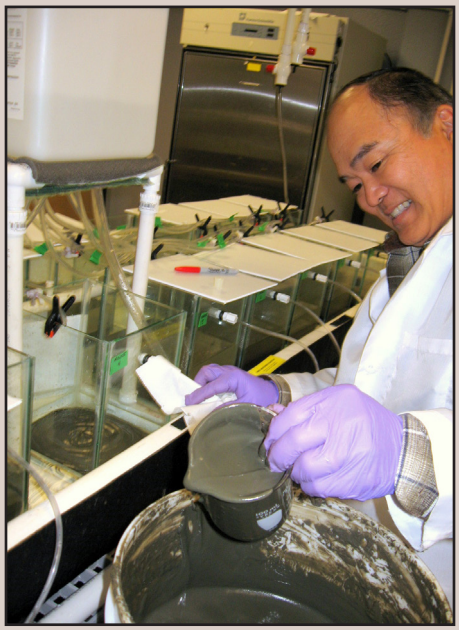
A 25-YEAR RETROSPECTIVE

Advances in sediment science over the past few decades have triggered a wholesale transformation in how environmental managers think about sediment quality. What was once an imprecise monitoring tool has evolved into a fully integrated, integral component of the decision-making framework. SCCWRP researchers have contributed in myriad ways to this progress, collaborating alongside scientists from around the world to continually refine the accuracy and utility of sediment quality tools and analysis methods.

Perhaps SCCWRP's greatest contribution, though, has been its focus on coalescing researchers, stakeholders and regulators around shared objectives, approaches and conclusions. In a discipline where disagreements and lack of consensus are inevitable byproducts of emerging research, SCCWRP has been a national leader in bringing all parties to the table to foster agreement and common understandings, as well as to work through concerns and criticisms. Furthermore, SCCWRP has worked proactively to generate interest and buy-in from the end-user environmental management community, helping to ensure that advances in sediment quality science are implemented efficiently and effectively.

SCCWRP's consensus-building strategy has been particularly effective in the development of California's Sediment Quality Objectives program to protect bottom-dwelling marine communities and humans; the program was based on SCCWRP-created assessment frameworks and went into effect in 2009 following rigorous review and vetting by all major entities affected by its policy implications. Because of this consistency in approach, today these frameworks are used in a variety of compliance and monitoring programs statewide.

What follows is a closer look at SCCWRP's research accomplishments in the sediment quality arena, organized around three main themes:



SCCWRP senior research technician David Tsukada transfers muddy sediment samples to exposure chambers during a bioaccumulation experiment.

method development, monitoring and assessment, and management application.

Method Development

SCCWRP has worked alongside leading researchers to improve the accuracy and refine the sensitivity of each of the three approaches used to measure sediment quality impacts: chemistry, toxicity and biology. SCCWRP also has investigated and advanced the science behind identifying chemicals that cause sediment quality contamination, a research area known as stressor identification.

CHEMISTRY

» **Sediment analysis methods:** SCCWRP has helped develop and improve analysis methods to measure the impacts of a number of known sediment contaminants, including the current-use pesticides Fipronil and pyrethroids, a now-banned class of industrial chemicals called PCBs (polychlorinated biphenyls), and contaminants of emerging concern, such as PBDE (polybrominated diphenyl ether) flame retardants. Interlaboratory comparisons and pilot studies coordinated by SCCWRP have helped local laboratories transition to using these new methods and have enhanced comparability of monitoring program data.

» **Passive sampling technology:** SCCWRP and its collaborators have developed a type of technology called passive sampling to measure organisms' exposure to sediment contaminants; this technology is now available to environmental managers. Passive sampling monitors the freely dissolved portion of sediment contaminants that surround the sediment particles; this portion is responsible for much of the exposure and toxic effects.

» **Guidelines and interpretation:** SCCWRP has helped lead the development of California's new sediment quality guidelines for interpreting chemistry data; SCCWRP

also has adapted national guidelines to California's sediment conditions. These guidelines have resulted in improved accuracy for predicting adverse biological effects and have been adopted by state water officials for use in regulatory programs.

TOXICITY

Sediment toxicity research by SCCWRP and its collaborators has led to the development of new sediment test methods and improved interpretation guidance for sediment toxicity data.

» **Assessment method development:** In collaboration with local laboratories and national experts, SCCWRP has evaluated candidate toxicity test methods and developed assessment methods that have been adopted by the California State Water Board for assessing compliance with the state's Sediment Quality Objectives program.

» **Comparison studies across labs:** Sediment toxicity data for Southern California monitoring programs have been improved through comparison studies coordinated by SCCWRP that compared toxicity test results across labs.

BIOLOGY

SCCWRP is among the world leaders in assessment of the condition of bottom-dwelling marine life, known as the benthic infauna community.

» **Benthic taxonomy analyses:** Early research by SCCWRP and its partners spurred formation of the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT), an organization that has catalogued and standardized benthic invertebrate taxonomy in the region, resulting in the highest-quality such taxonomic analyses in the nation.

Courtesy of Hal Beral

An elegant tern, left, holds onto a fish that will likely feed newly hatched chicks at Bolsa Chica Ecological Reserve in Huntington Beach. Several species of seabirds that nest along Southern California's coast have been shown to experience reproductive problems because of sediment contaminants that bioaccumulate in their bodies.

Courtesy of Sarah Lowe, San Francisco Estuary Institute

A field technician retrieves a grab sampler containing surface sediment from the Sacramento and San Joaquin River Delta. Data from sediment quality surveys conducted and coordinated by SCCWRP have provided the foundation for developing improved sediment quality assessment methods statewide.

» **Benthic index development:** SCCWRP has been at the forefront of developing improved indices to assess benthic infauna community condition, including the Benthic Response Index, which was adopted for use by the National Pollutant Discharge Elimination System's ocean-monitoring programs.

» **Benthic assessment programs:** SCCWRP has helped create some of the most comprehensive and sophisticated benthic community assessment programs in the nation. Extensive databases from monitoring programs coordinated by SCCWRP have been used to identify key benthic community assemblage types in California, as well as supported development and calibration of habitat-specific benthic indices that are now being used in regulatory and monitoring programs to evaluate sediment quality. Critical to the development of these benthic evaluation programs has been SCCWRP's success coordinating expert panels and technical workgroups to develop consensus among scientists in the interpretation of benthic community data.

STRESSOR IDENTIFICATION

SCCWRP is one of the leading authorities in the development and application of methods to determine the cause of sediment quality impacts, a process known as stressor identification.

» **Toxicity identification evaluation:** Through development of Toxicity Identification Evaluation (TIE) methods by SCCWRP and its collaborators, researchers have been able to show that most sediment toxicity in Southern California's embayments is related to synthetic organic contaminants, primarily current-use pesticides discharged via stormwater.

» **Consensus-building:** SCCWRP's TIE research hasn't been limited solely to sediment sample analysis; the agency also has hosted a number of workshops and technical committees aimed at developing a high degree of consensus among experts in the field

Courtesy of Amec Foster Wheeler

Sediment varies dramatically in its physical characteristics, as demonstrated by these two samples collected just inches apart by a double Van Veen grab sampler. Characteristics such as particle size and organic carbon content can influence how sediment contaminants impact bottom-dwelling marine communities.

regarding TIE methods.

» **Molecular TIE development:** SCCWRP and its collaborators have worked at the forefront of molecular technology to develop new stressor identification methods. Recent efforts have produced tools capable of measuring gene expression in sediment test organisms, offering greater sensitivity than is possible with traditional TIE methods.

Monitoring and Assessment

Early sediment quality studies conducted by SCCWRP in the Southern California Bight were among the first to show the broad impacts of wastewater discharge and urban and agricultural runoff on sediment, and the agency has helped push the boundaries of regional monitoring ever since. Continued efforts to improve monitoring program design have facilitated a transition from narrowly focused studies to sweeping regional studies that have served as national models for effective monitoring.

» **High-quality regional data:** By consolidating disparate monitoring approaches under the Southern California Bight Regional Monitoring Program, SCCWRP and its dozens of program partners have rewritten scientists' understanding of the spatial extent, magnitude and impacts of sediment contamination along California's coastline. The Bight program, designed and implemented cooperatively every five years, features a robust statistical design that generates high-quality data that are widely used as the benchmark for assessing the status and trends of Southern California sediment quality.

» **Improved methods and perspective:** Among the many strengths of the Bight monitoring program is its ability to evaluate new technologies, including passive sampling, and to continually expand to monitor little-studied habitats, including submarine canyons and deep-slope areas. From these efforts, Bight participants have developed improved monitoring methods and a more complete perspective on contamination status and trends in Southern California.

Management Application

The products of sediment quality research and monitoring activities by SCCWRP and its collaborators have had impacts on environmental management programs and activities at the local, state and national levels.

» **Standardized protocols:** Many of the methods for chemistry, toxicity and biological assessments developed by SCCWRP and its partners have become standard protocols for Southern California monitoring programs.

» **Context for data interpretation:** The data sets and synthesis generated from regional monitoring efforts in Southern California have provided the context that program managers need to interpret site-specific results.

» **Implementation of state regulations:** At the state level, SCCWRP-led research has generated the technical foundation for the sediment quality assessment frameworks used to implement California's Sediment Quality Objectives program for protection of benthic communities and human health.

» **Technology transfer:** To facilitate use of the California sediment quality assessment frameworks among regional and local agencies, SCCWRP has worked alongside its partners and member agencies to develop data analysis tools, guidance manuals and training workshops. Environmental managers, in turn, have begun incorporating these frameworks into regulatory monitoring programs and Total Maximum Daily Load targets intended to reduce a water body's contamination levels.

» **National impacts:** Sediment quality research by SCCWRP has had impacts on a national scale. Methodologies for benthic community assessment and toxicity testing have been incorporated into monitoring programs across the nation, and the regional monitoring expertise developed through the Bight program and others has served as a model for monitoring programs in other states and at the federal level. Also, because SCCWRP scientists are frequently invited to serve on national advisory panels alongside other leading sediment quality experts, the impact of the research by SCCWRP and its collaborators is magnified across multiple federal agencies.

Accomplishments

While SCCWRP has devoted significant space in this year's Annual Report to exploring advances in sediment quality research, the agency works across a number of other thematic research arenas. What follows is an overview of key milestones and accomplishments within each of nine major research areas. The write-ups for each research area are accompanied by scientific abstracts for all peer-reviewed journal articles and reports from 2014 that relate to the research area. In all, 38 articles and reports co-authored by SCCWRP scientists are featured.

SCCWRP Research Areas

Microbial Water Quality

With runoff and discharge introducing potentially pathogenic waterborne microbes into coastal waters, especially at populated beaches, SCCWRP is working to more rapidly detect beach microbial contamination and to advance the breadth and accuracy of emerging source-identification technologies. To characterize the risk of water-contact illness, epidemiological and modeling studies are being conducted.

Eutrophication

With anthropogenic nutrient inputs a leading cause of eutrophication – or accelerated accumulation of organic matter in aquatic habitats – SCCWRP is working to help environmental managers understand the deleterious impacts of excessive nutrients in both freshwater and coastal waters by diagnosing eutrophication, identifying appropriate nutrient targets, and tracking where nutrients are coming from and what is happening to them.

Contaminants of Emerging Concern

To prioritize tens of thousands of known but inadequately studied contaminants of emerging concern (CECs) in water bodies for monitoring and risk assessment, SCCWRP is developing novel approaches to more widely and efficiently screen for CECs, as well as working to predict the impacts of high-priority CECs, characterize key exposure routes, and connect screening-level monitoring data to higher-level biological responses.

Bioassessment

As environmental managers increasingly turn to measuring the health of aquatic ecosystems through biological assessments – or bioassessment – SCCWRP is building tools that evaluate the condition of benthic invertebrates, algae and other life forms to assess streams, wetlands and nearshore marine environments.

Sediment Quality

Intrinsic to documenting the impacts of contamination flushed into coastal waters is studying how it settles and binds to sediment particles, and then is taken up by bottom-dwelling aquatic life. SCCWRP is working to more precisely measure how contamination enters food webs, the resulting impacts to biological communities, and bioaccumulation effects in higher-level organisms.

Flow Ecology

While environmental managers have historically focused on the role that runoff from urban and agricultural surfaces plays in transporting and depositing pollutants, water flow also can impact the physical environment of streams. SCCWRP is working to understand and predict these hydrologic and physical alterations, and to relate them to how biological communities respond.

Wetlands

As state and federal policies have prioritized protection and restoration of wetland areas and the many beneficial uses they provide, SCCWRP has been working to develop tools and approaches for mapping wetlands that rely on advanced technologies and statistical approaches to assess their condition and value to society.

Regional Monitoring

To provide comprehensive assessments of the health of coastal waters and the watersheds that feed into them, SCCWRP is facilitating the design and execution of regional, multi-agency monitoring programs that can answer big-picture ecosystem questions. Ongoing signature efforts include the Southern California Bight Regional Monitoring Program and its Regional Stream Monitoring counterpart.

Information Technology and Visualization

With an ever-present need to improve the technology used to monitor and assess aquatic ecosystems, SCCWRP is working to build next-generation tools that enhance the environmental management community's ability to collect, store, standardize, share and visualize data.

Microbial Water Quality

SCCWRP Accomplishments

With more than 125 million visits per year, Southern California's beaches are a precious natural resource and a major economic driver for the state and region. As such, protecting beachgoers from waterborne microbes that come from a disparate array of sources is vital to maintaining the economic benefits and perception of healthful living associated with California beach culture. Although California runs the nation's most comprehensive beach water monitoring program, the public could benefit greatly from advances in how microbial water contamination is monitored and detected. Existing methods take 24 hours or more to yield results, which isn't fast enough to provide same-day warnings to beachgoers. Moreover, when environmental managers find fecal indicator bacteria that may be associated with potentially pathogenic microbes in water, they want to identify where the contamination is coming from to stop it at the source. Given that waterborne microbes can travel long distances, remain infectious for extended periods (as in the case of some viruses), and come from any combination of human and animal feces, the process of identifying sources of microbial water contamination can be challenging and complex − an area for which the technology is still evolving. SCCWRP has been at the forefront of efforts to more rapidly detect beach microbial contamination and to advance the breadth and accuracy of emerging source-identification technologies. Working with its collaborators, SCCWRP has evaluated methods for identifying fecal sources, created a tiered framework for investigating sources of fecal bacteria at beaches, and developed and evaluated multiple assays designed to measure pathogens in both fresh and marine water. SCCWRP also is actively involved in applying these methodologies to epidemiology and modeling studies to characterize the risk of water-contact illness.

SCCWRP's microbial water quality research is focused around three major objectives: (1) Develop methods to provide same-day health warnings to ocean bathers, (2) improve the approaches used to identify sources of microbial contamination, and (3) understand the relationships between contamination measurements and observed impacts on human health. The first two areas revolve around transitioning from decades-old, culture-based analyses − in which microbes must grow for 24 hours in a lab − to genetic methods capable of rapidly detecting and quantifying microbes via the presence of their genetic material (DNA or RNA). This genetic technology also has the potential to provide important information about the source of fecal contamination, as specific genetic targets are diagnostic of different fecal sources (e.g., humans, dogs, cows, birds). Given the trove of data that these emerging technologies can yield, SCCWRP is working to incorporate these methods into epidemiological studies that can help environmental managers better understand the health risks associated with various beaches and fecal sources. SCCWRP's ultimate goal is to provide managers with real-time information on sources of fecal contamination and commensurate risk to public health.

Over the past year, SCCWRP has been pursuing research toward evaluating and implementing source-associated fecal markers, developing guidance for conducting fecal source identification studies, examining the relative degradation of source-associated markers compared to fecal indicator bacteria and pathogens, and developing an instrument to autonomously measure microbes in the field. These studies have opened new avenues of possibility for how beach managers might conduct fecal source identification studies. Accomplishments in 2014 include:

» **Reaching international consensus on the most effective fecal source identification markers:** In the largest and most comprehensive study of its kind, SCCWRP and 27 collaborators across the nation and Europe have come to agreement on a set of DNA markers that are highly effective at identifying sources of fecal contamination in aquatic environments. The study, which included the world's top scientists in the field of microbial source tracking, evaluated 41 markers, arriving at consensus about which are both sensitive and specific for their targets. The study was so successful that one of the top scientific journals in the field, *Water Research*, dedicated a full issue to the study's findings.

» **Penning California's microbial source identification manual:** Building upon the success of the international genetic marker evaluation study, SCCWRP and its collaborators have published a new, state-commissioned manual designed to help California's coastal cities identify sources of fecal bacteria contamination at their beaches. The manual, published in 2014, describes a tiered approach for conducting microbial source identification studies, starting with collecting existing data and information from stakeholders and employing well-tested and less costly methods; then, the manual advises progressing to more expensive alternatives, such as tracking source-associated fecal DNA markers. The protocols described in the manual are now required for all microbial source identification studies funded by the state.

» **Tracking health impacts from surfing after rainfall:** A first-of-its-kind study aiming to ascertain whether the health of surfers during Southern California's rainy winter

months is impacted by stormwater runoff has successfully finished its pilot run, paving the way for completion of a full-scale study in early 2015. The Surfer Health Study, set to be published in 2016, focuses on assessing whether microbes carried by rainfall runoff (which flows through storm drains to the ocean) make surfers sick. The study builds upon the findings of previously published epidemiology work that was focused on ocean swimmers and bathers during summer months; SCCWRP's study will be the first to assess illness rates associated with stormwater runoff during the winter months. The first component of the study involves asking surfers who use those beaches from December to March to report how often they entered the ocean and any illnesses they experienced during that period. The second component involves measuring fecal indicator bacteria and pathogen levels at two San Diego beaches throughout the winter and after rain events. The surfer health data, combined with the microbial data, will be used to determine whether the water-quality standards developed for dry-weather summer conditions are also the most appropriate for rainy winter conditions.

Effect of submarine groundwater discharge on bacterial indicators and swimmer health at Avalon Beach, CA, USA

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Abstract

Use of fecal indicator bacteria (FIB) for monitoring beach water quality is based on their cooccurrence with human pathogens, a relationship that can be dramatically altered by fate and transport processes after leaving the human intestine. We conducted a prospective cohort study at Avalon Beach, California (USA), where the indicator relationship is potentially affected by the discharge of sewage-contaminated groundwater and by solar radiation levels at this shallow, relatively quiescent beach. The goals of this study were to determine: 1) if swimmers exposed to marine water were at higher risk of illness than nonswimmers; 2) if FIB measured in marine water were associated with swimmer illness, and; 3) if the associations between FIB and swimmer health were modified by either submarine groundwater discharge or solar radiation levels. There were 7317 individuals recruited during the summers of 2007-08, 6165 (84%) of whom completed follow-up within two weeks of the beach visit. A total of 703 water quality samples were collected across multiple sites and time periods during recruitment days and analyzed for FIB using both culture-based and molecular methods. Adjusted odds ratios (AOR) indicated that swimmers who swallowed water were more likely to experience Gastrointestinal Illness (GI Illness) within three days of their beach visit than non-swimmers, and that this risk wassignificantly elevated when either submarine groundwater discharge was high (AOR [95% CI]:2.18 [1.22-3.89]) or solar radiation was low (2.45 [1.25-4.79]). The risk of GI Illness was not significantly elevated for swimmers who swallowed water when groundwater discharge was low or solar radiation was high. Associations between GI Illness incidence and FIB levels (Enterococcus EPA Method 1600) among swimmers who swallowed water were not significant when we did not account for groundwater discharge, but were strongly associated when groundwater discharge was high (1.85 [1.06, 3.23]) compared to when it was low (0.77 [0.42, 1.42]; test of interaction: P = 0.03). These results demonstrate the need to account for local environmental conditions when monitoring for, and making decisions about, public health at recreational beaches.

Citation

Yau, VM, KC Schiff, BF Arnold, JF Griffith, JS Gruber, CC Wright, TJ Wade, S Burns, JM Hayes, C McGee, M Gold, Y Cao, AB Boehm, SB Weisberg, JM Colford Jr. 2014. Effect of submarine groundwater discharge on bacterial indicators and swimmer health at Avalon Beach, CA, USA. *Water Research* 59:23-36. doi:10.1016/j.watres.2014.03.050.

SCCWRP Journal Article #0825
Full text available by request: pubrequest@sccwrp.org

Detection limits and cost comparisons of human- and gull-associated conventional and quantitative PCR assays in artificial and environmental waters

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Abstract

Some molecular methods for tracking fecal pollution in environmental waters have both PCR and quantitative PCR (qPCR) assays available for use. To assist managers in deciding whether to implement newer qPCR techniques in routine monitoring programs, we compared detection limits (LODs) and costs of PCR and qPCR assays with identical targets that are relevant to beach water quality assessment. For human-associated assays targeting Bacteroidales HF183 genetic marker, qPCR LODs were 70 times lower and there was no effect of target matrix (artificial freshwater, environmental creek water, and environmental marine water) on PCR or qPCR LODs. The PCR startup and annual costs were the lowest, while the per reaction cost was 62% lower than the Taqman based qPCR and 180% higher than the SYBR based qPCR. For gull-associated assays, there was no significant difference between PCR and qPCR LODs, target matrix did not effect PCR or qPCR LODs, and PCR startup, annual, and per reaction costs were lower. Upgrading to qPCR involves greater startup and annual costs, but this increase may be justified in the case of the human-associated assays with lower detection limits and reduced cost per sample.

Citation

Riedel, TE, AG Zimmer-Faust, V Thulsiraj, T Madi, KT Hanley, DL Ebentier, M Byappanahalli, B Layton, M Raith, AB Boehm, JF Griffith, PA Holden, OC Shanks, SB Weisberg, JA Jay. 2014. Detection limits and cost comparisons of human-and gull-associated conventional and quantitative PCR assays in artificial and environmental waters. *Journal of Environmental Management* 136:112-120. doi:10.1016/j.jenvman.2014.01.029.

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Comparison of Enterococcus species diversity in marine water and wastewater using Enterolert and EPA Method 1600

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Abstract

EPA Method 1600 and Enterolert are used interchangeably to measure *Enterococcus* for fecal contamination of public beaches, but the methods occasionally produce different results. Here we assess whether these differences are attributable to the selectivity for certain species within the *Enterococcus* group. Both methods were used to obtain 1279 isolates from 17 environmental samples, including influent and effluent of four wastewater treatment plants, ambient marine water from seven different beaches, and freshwater urban runoff from two stream systems. The isolates were identified to species level. Detection of non-*Enterococcus* species was slightly higher using Enterolert (8.4%) than for EPA Method 1600 (5.1%). *E. faecalis* and *E. faecium*, commonly associated with human fecal waste, were predominant in wastewater; however, Enterolert had greater selectivity for *E. faecalis*, which was also shown using a laboratory-created sample. The same species selectivity was not observed for most beach water and urban runoff samples. These samples had relatively higher proportions of plant associated species, *E. casseliflavus* (18.5%) and *E. mundtii* (5.7%), compared to wastewater, suggesting environmental inputs to beaches and runoff. The potential for species selectivity among water testing methods should be considered when assessing the sanitary quality of beaches so that public health warnings are based on indicators representative of fecal sources.

Citation

Ferguson, DM, JF Griffith, CD McGee, SB Weisberg, C Hagedorn. 2013. Comparison of *Enterococcus* species diversity in marine water and wastewater using Enterolert and EPA Method 1600. *Journal of Environmental and Public Health* 2013:848048.

SCCWRP Journal Article #0788
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/AnnualReports/2010AnnualReport/ar10_067_073.pdf

EUTROPHICATION

SCCWRP Accomplishments

While not inherently harmful, excess nutrients introduced to aquatic habitats through human activity (i.e. nitrogen and phosphorus) can trigger eutrophication, the accelerated accumulation of organic matter from overgrowth of aquatic plants and algae. These aquatic blooms can be unsightly and, in some cases, produce toxins and noxious odors. They also can lead to low dissolved-oxygen levels, which trigger declines in fishery harvests and in diversity of aquatic life. However, determining the load of nutrients a water body can sustainably assimilate is challenging because, unlike contaminants, some level of nutrient input is necessary to sustain life. Consequently, environmental managers must work to control the deleterious impacts of excessive nutrients. SCCWRP has been at the forefront of eutrophication research efforts in both freshwater and coastal-ocean systems, working to build a rigorous body of science capable of diagnosing eutrophication, identifying appropriate nutrient targets for California's water bodies, and tracking where nutrients are coming from and what is happening to them. In inland waters, SCCWRP is serving as the technical lead on a multi-year effort by the State Water Board to develop a nutrient objectives policy to protect all of California's wadeable streams, lakes and estuaries. In coastal waters, SCCWRP is studying if and how anthropogenic nutrient inputs to the Southern California Bight are contributing to eutrophication, particularly with respect to increasing algal blooms and acidification (low pH) and declines in dissolved oxygen.

Although the symptoms of eutrophication vary by water body type, the conceptual approach to developing tools to diagnose eutrophication and identify nutrient targets is similar for all water bodies. The first step is to build consensus around a conceptual model that identifies symptoms of eutrophication (e.g., altered dissolved oxygen concentrations, increased algal abundance) and their link to both nutrient loads and other contributing water body factors. The second step is to design a framework for assessing the condition of a water body, one that focuses on eutrophication symptoms instead of nutrients themselves. An important element of this framework is to identify thresholds for each symptom that equate to protection of human and ecosystem values and avoidance of adverse impacts. The third step is to build statistical and mechanistic models that link eutrophication symptoms to nutrients and other factors to examine environmental-management scenarios that might prevent an ecosystem impact. An important element of mechanistic model development is conducting process studies that document the fate of nutrients as they are cycled through an aquatic habitat. The final step is to assist in transferring this technology to environmental managers.

Over the past year, SCCWRP has been working to incrementally build the knowledge base and the technical foundation that will allow nutrient inputs to be more effectively monitored and controlled in California, both on land and offshore. Key accomplishments in 2014 include:

» **Establishing eutrophication-impact thresholds for California's streams:** A new study of California's wadeable streams, authored by SCCWRP and published by the U.S. Environmental Protection Agency, has identified a clear, narrow range of thresholds at which algal abundance, one of the key indicators of eutrophication, correlates with adverse impacts on stream aquatic life. Approximately 17% of the state's wadeable stream network exceeded the mean algal-abundance threshold identified by the study. Furthermore, 40% of streams within the South Coast region exceeded this threshold, suggesting that stream eutrophication is primarily a problem in areas dominated by urban and agricultural development. This study marks an important step forward in scientists' effort to build a framework to assess eutrophication and a scientific foundation for establishing nutrient objectives in wadeable streams.

» **Tracking toxic cyanobacteria and cyanotoxin production in California:** A three-year study of California's freshwater and coastal systems has found that toxins from photosynthetic bacterial blooms were widespread across the wadeable streams, lakes, ponds and estuaries sampled – including in water bodies thought to be unaffected by human activity. The study, conducted by SCCWRP and its collaborators and set to be published in 2015, is the first to document how prevalent toxic cyanobacteria are in Southern California Bight watersheds. Scientists have linked cyanobacteria proliferation to anthropogenic nutrient inputs, but don't know to what degree natural factors and climate change also may be responsible. Given how toxic the cyanobacteria can be to aquatic ecosystems and land mammals, including humans, SCCWRP is working to quantify the scope of the problem and to track its root causes. SCCWRP also has been asked to lead development of a statewide cyanobacteria monitoring strategy, set to kick off in 2015.

» **Studying biogeochemical effects of wastewater effluent:** A short-term, small-scale biogeochemical study

examining how coastal ecosystems are affected by wastewater effluent has demonstrated that introduction of wastewater nutrients to the area immediately surrounding an outfall triggers rapid nutrient cycling. During the study, conducted in 2012 and set to be published in 2015, wastewater was diverted from an Orange County outfall undergoing repairs to a second outfall closer to shore. Researchers found that ammonia from the effluent was being rapidly converted to nitrate, possibly becoming a significant nitrogen source for heterotrophic bacteria, a type of bacteria that consumes oxygen as it decomposes organic matter. This study served as a proof of concept for an expanded set of process studies that are investigating the effects of wastewater effluent on nutrient and organic matter cycling. The goal is to use the data from these studies to validate dynamic ecosystem models that predict the extent to which wastewater effluent discharged to Southern California Bight ocean outfalls is affecting algal blooms, dissolved oxygen and pH levels.

Estimating wet and dry deposition of nitrogen to Southern California streams: Final report of IA DW-12-92326401-0

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ABSTRACT

The purpose of this report is to summarize the findings of a research study designed to characterize the flux of atmospheric nutrients to Southern California watersheds conducted with the support of the U.S. Environmental Protection Agency under Interagency Agreement DW 12923264010. Atmospheric deposition (wet and dry) is potentially one source of "background" nutrients to streams. The load of nutrients to aquatic habitats from atmospheric deposition, relative to other potential sources of nutrients, are not well characterized in California. In particular, little data are available on the dry deposition of atmospheric nutrients, which may constitute roughly 90% of the total annual atmospheric loads in semi-arid regions. Studies were conducted to address the following research objectives:

- Evaluate methods for assessment of wet and dry deposition rates of nitrogen and phosphorus from the atmosphere.
- Estimate the spatial and temporal variability in nitrogen and phosphorus deposition from the atmosphere to five, relatively undisturbed catchments in Southern California.
- Evaluate the utility of stable isotopic tracers, specifically the dual isotopes of nitrate ($\delta^{18}O$ and $\delta^{15}N$) to assess the contribution of atmospheric nitrate to reference streams.

Following are the major findings of this study:

(1) Of the surrogate surfaces tested under controlled circumstances, the water surface samplers seemed to produce the most reliable results.

(2) Across all sites, dry nitrogen and phosphorus deposition was a significant fraction of the total annual atmospheric deposition of nutrients (average nitrogen dry deposition is ~70% and average phosphorus dry deposition is ~30% of the total load), demonstrating the importance of characterizing this fraction when assessing atmospheric nutrient loads.

(3) In Southern California there has been an assumption that nitrogen deposition should be dominated by oxidized forms of nitrogen due to domination by automobile exhaust; however this study shows that is not necessarily the case.

(4) The dual isotopic signatures of $\delta^{18}O$ and $\delta^{15}N$ in atmospheric nitrate deposition in Southern California is consistent with literature values for atmospheric nitrate showing characteristically high $\delta^{18}O$ values. The distinctiveness of the high $\delta^{18}O$ value for atmospheric nitrate across all sites suggests that the dual isotopic composition of nitrate could be an excellent tracer for direct deposition of atmospheric nitrate into water bodies.

However, this is not to say that atmospheric deposition is not a significant source of nitrate to streams; rather, atmospheric deposition of nutrients is more likely indirectly accumulated in streams, by first depositing on the landscape and entering the streams through surface runoff or groundwater.

CITATION

McLaughlin, K, M Sutula. 2014. Estimating wet and dry deposition of nitrogen to Southern California streams: Final report of IA DW-12-92326401-0. Technical Report 837. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0837
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/837_EPA_ORD_Final_Report_V4.pdf

Linking nutrients to alterations in aquatic life in California wadeable streams

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ABSTRACT

In wadeable streams, nutrient enrichment, in concert with other site-specific factors, can result in the overabundance of algal biomass, low dissolved oxygen and altered biotic communities. These changes can have adverse effects on stream ecosystem services. Scientifically-based water quality objectives (WQO) and tools that relate these objectives to nutrient management are needed in California to prevent eutrophication from occurring and to provide

targets to restore waterbodies where adverse effects have already occurred.

The California State Water Resources Control Board (SWRCB) is developing nutrient water quality objectives for the State's surface waters. USEPA guidance on nutrient objective development generally recommends three means to set nutrient objectives (USEPA 2000): 1) a reference approach, based on a statistical percentile of nutrient or biotic response indicators in minimally-disturbed waterbodies; 2) an empirical stress-response approach, based on statistical analyses of field data on nutrients, algal abundance and indicators of aquatic life; or 3) a process-based approach, involving identification of ecological responses of concern and mechanistically modeling the linkage back to nutrient loads and other co-factors controlling response.

Among the approaches that the SWRCB staff is considering is the process-based approach, known as the Nutrient Numeric Endpoint (NNE) framework. The NNE framework is intended to serve as numeric guidance to translate narrative WQO. It consists of two tenets: 1) assessment and recommended numeric (regulatory) endpoints based on the ecological response of an aquatic waterbody to eutrophication (e.g., algal abundance, dissolved oxygen [DO]) to assess waterbody condition and 2) scoping-level models that link the response indicator endpoints to nutrient inputs and other site-specific factors and management controls. These scoping models were intended to be used to establish default nutrient targets for point source discharge and municipal stormwater permits and total maximum daily loads. Tetra Tech developed the benthic biomass spreadsheet tool (BBST) for use in streams. As the SWRCB prepares to propose nutrient objectives for wadeable streams, scientific analyses of improved data from California statewide stream probabilistic and targeted bioassessment surveys can strengthen the scientific basis for policy decisions. In the context of this study, "endpoints" refer to policy decisions on levels at which point management action should be taken; "thresholds" refer to the output of scientific analyses.

The objectives of this project are three-fold:

- Estimate the natural background and ambient concentrations of nutrients and candidate indicators of primary producer abundance in California wadeable streams;
- Explore relationships and identify thresholds of adverse effects of nutrient concentrations and primary producer abundance on aquatic life indicators in California wadeable streams;
- Evaluate the Benthic Biomass Spreadsheet Tool for California wadeable streams using existing data sets and recommend avenues for refinement.

The intended outcome of this study is research, NOT recommendations for regulatory endpoints for nutrient and response indicators for California wadeable streams. The findings of this research study, as well as other analyses, may be used as lines of evidence considered to support SWRCB policy decisions on nutrient objectives for wadeable streams.

Study findings

The majority of the State's Wadeable Streams sampled are below the 75th percentile of minimally disturbed "reference sites." California's perennial, wadeable streams, as assessed during the bioassessment index period of late spring through mid-summer, exhibited a skew toward the low end of the primary producer abundance gradient. Nearly 66% of perennial wadeable stream kilometers had estimated benthic chlorophyll a and 59% had estimated TN and TP values below the 75th percentile of each variable at reference sites statewide. Among the regions, a gradient in algal abundance and nutrient concentrations was observed from high in areas developed by urban and agricultural land uses (South Coast, Central Valley) to low in areas of the state with lower density development (e.g., North Coast and Sierra regions).

Statistically detectable thresholds were found for benthic chlorophyll a, ash-free dry mass (AFDM), and nutrients; benthic chlorophyll a thresholds were below those of TetraTech. This study found statistically significant relationships and thresholds of adverse effects of benthic chlorophyll a, AFDM, and TN and TP concentrations on indicators of benthic macroinvertebrate (BMI) and algal community structure—employed in this study as indicators of aquatic life. Integrative aquatic life indicators (ALIs) such as indices of biotic integrity corresponded to higher thresholds whereas ALI measures specific to constrained groups of "sensitive" taxa generally corresponded to lower thresholds, illustrative of the paradigm of the biological condition gradient. Most of these thresholds of effect exceeded the 75th percentile of these indicators among reference stream reaches statewide, but they were often less than the 95th percentile. The range of benthic chlorophyll a thresholds in this study were generally substantially below the current NNE endpoints protective of beneficial uses recommended by TetraTech (100 and 150 mg/m^2 chlorophyll a for cold [salmonid] and warm water, respectively). However, it should be noted that our results are based on instantaneous measurement at low-flow conditions, and as such, do not reflect year-long loads or storm flows. It is not clear to what degree the types of ALI-stressor relationships we observed would hold during rain events.

Validation exercise indicates that there is considerable room for improvement in BBST; inclusion of landscape and site-scale factors provide avenue for model refinement. The BBST models show poor fit, particularly among "stressed" sites (one-third of the data set), when validated against a statewide dataset, which contains benthic chlorophyll a data as currently measured in California ambient monitoring programs. The poor fit is understandable, given that the BBST was optimized for North American temperate streams and that the model predicts maximum algal abundance, a value not verifiably captured during the period in which sampling to generate the project data set occurred. Several landscape- and site-scale explanatory variables were high

in their relative influence in the BBST model predicted-observed variance analysis and in preliminary nutrient-algal response models. Nutrient concentrations were important predictors in BBST model predicted-observed variance analysis and boosted regression tree (BRT) models, albeit occupying less prominent roles than other factors, such as temperature and stream substratum type. This finding validates the fundamental NNE approach: site-specific co-factors that vary across the California landscape can influence algal response to nutrients. It also suggests that model refinements are possible; inclusion of these site- and landscape-scale explanatory variables in preliminary nutrient-algal response models substantially improved model fit over existing BBST models.

Citation

Fetscher, E, M Sutula, A Sengupta, N Detenbeck. 2014. Linking Nutrients to Alterations in Aquatic Life in California Wadeable Streams. Technical Report 834. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0834
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/834_RESERVreport_06oct14Final.pdf

Patterns and potential drivers of declining oxygen content along the Southern California coast

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Abstract

Here we examine a 50+ yr data set from a regionally coordinated Southern California water quality monitoring program to assess temporal trends and determine whether nearshore waters are exhibiting changes in dissolved oxygen (DO) content similar to those reported offshore. DO in sub–mixed layer nearshore waters (< 10 km from shore) have declined up to four times faster than reported for offshore waters over the last 15 yr. These trends were evident over depth, and along isopycnals. They have no precedent over the past 50 yr and do not appear to be attributable primarily to large-scale climate variability in ocean DO. Coastal biophysical processes, including increased phytoplankton biomass in surface waters, are likely contributing to the recent elevated rate of DO decline in nearshore waters, as evidenced by higher rates of increase in apparent oxygen utilization. It is unclear whether these processes result from upwelling-derived or anthropogenic nutrient inputs.

Citation

Booth, JAT, CB Woodson, M Sutula, F Micheli, SB Weisberg, SJ Bograd, A Steele, J Schoen, LB Crowder. 2014. Patterns and potential drivers of declining oxygen content along the Southern California coast. *Limnology and Oceanography* 59:1127–1138. doi:10.4319/lo.2014.59.4.1127.

SCCWRP Journal Article #0827
Full text available by request: pubrequest@sccwrp.org

Anthropogenic nutrient sources rival natural sources on small scales in the coastal waters of the Southern California Bight

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Abstract

Anthropogenic nutrients have been shown to provide significant sources of nitrogen (N) that have been linked to increased primary production and harmful algal blooms worldwide. There is a general perception that in upwelling regions, the flux of anthropogenic nutrient inputs is small relative to upwelling flux, and therefore anthropogenic inputs have relatively little effect on the productivity of coastal waters. To test the hypothesis that natural sources (e.g., upwelling) greatly exceed anthropogenic nutrient sources to the Southern California Bight (SCB), this study compared the source contributions of N from four major nutrient sources: (1) upwelling, (2) treated wastewater effluent discharged to ocean outfalls, (3) riverine runoff, and (4) atmospheric deposition. This comparison was made using large regional data sets combined with modeling on both regional and local scales. At the regional bight-wide spatial scale, upwelling was the largest source of N by an order of magnitude to effluent and two orders of magnitude to riverine runoff. However, at smaller spatial scales, more relevant to algal bloom development, natural and anthropogenic contributions were equivalent. In particular, wastewater effluent and upwelling contributed the same quantity of N in several subregions of the SCB. These findings contradict the currently held perception that in upwelling-dominated regions anthropogenic nutrient inputs are negligible, and suggest that anthropogenic nutrients, mainly wastewater effluent, can provide a significant source of nitrogen for nearshore productivity in Southern California coastal waters.

Citation

Howard, MDA, M Sutula, DA Caron, Y Chao, JD Farrara, H Frenzel, B Jones, G Robertson, K McLaughlin, A Sengupta. 2014. Anthropogenic nutrient sources rival natural sources on small scales in the coastal waters of the Southern California Bight. *Limnology and Oceanography* 59:285–297. doi:10.4319/lo.2014.59.1.0285.

SCCWRP Journal Article #0810
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Phosphorus cycling in the Sargasso Sea: Investigation using the oxygen isotopic composition of phosphate, enzyme-labeled fluorescence, and turnover times

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Abstract

Dissolved inorganic phosphorus (DIP) concentrations in surface water of vast areas of the ocean are extremely low (<10 nM) and phosphorus (P) availability could limit primary productivity in these regions. We explore the use of oxygen isotopic signature of dissolved phosphate (d18OP04) to investigate biogeochemical cycling of P in the Sargasso Sea, Atlantic Ocean. Additional techniques for studying P dynamics including 33P-based DIP turnover time estimates and percent of cells expressing alkaline phosphatase (AP) activity as measured by enzyme-labeling fluorescence are also used. In surface waters, d18OP04 values were lower than equilibrium by 3–6%, indicative of dissolved organic phosphorous (DOP) remineralization by extracellular enzymes. An isotope mass balance model using a variety of possible combinations of enzymatic pathways and substrates indicates that DOP remineralization in the euphotic zone can account for a large proportion on P utilized by phytoplankton (as much as 82%). Relatively short DIP turnover times (4–8 h) and high expression of AP (38–77% of the cells labeled) are consistent with extensive DOP utilization and low DIP availability in the euphotoc zone. In deep water where DOP utilization rates are lower, d18OP04 values approach isotopic equilibrium and DIP turnover times are longer. Our data suggests that in the euphotic zone of the Sargasso Sea, DOP may be appreciably remineralized and utilized by phytoplankton and bacteria to supplement cellular requirements. A substantial fraction of photosynthesis in this region is supported by DOP uptake.

Citation

McLaughlin, K, JA Sohm, GA Cutter, MW Lomas, A Paytan. 2013. Phosphorus cycling in the Sargasso Sea: Investigation using the oxygen isotopic composition of phosphate, enzyme-labeled fluorescence, and turnover times. *Global Biogeochemical Cycles* 27:375-387.

SCCWRP Journal Article #0758
Full text available by request: pubrequest@sccwrp.org

Science supporting dissolved oxygen objectives for Suisun Marsh

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Abstract

At the request of the San Francisco Bay Regional Water Quality Control Board, the potential for deriving site-specific water quality criteria for dissolved oxygen (DO) in Suisun Bay and Marsh was evaluated. Fish and invertebrate species representative of Suisun Bay and Marsh were identified from the literature and screened against currently available data on sensitivity to low levels of DO (i.e., hypoxia). It was determined that sufficient data were available for either locally-occurring species or their genus or family level surrogates to calculate values for both the acute criterion minimum concentration (CMC) and chronic criterion continuous concentration (CCC) for DO using USEPA procedures for deriving water quality criteria. The CMC is designed to protect the survival of juvenile and adult organisms under short term exposure conditions, whereas the CCC is designed to protect organisms from adverse effects on survival, growth and reproduction related to long-term (i.e., indefinite) exposure. The calculated criteria varied, depending upon which species were included, with the most sensitive species being sturgeon and salmon. Based on analysis of the available date, the criteria are shown below:

Species Represented	CMC (Mg/L)	CCC (Mg/L)
General, without Sturgeon	3.0	4.8
General, with Sturgeon	3.3	5.0
General, with Sturgeon and Salmonids	3.3	6.2

These criteria were compared with a subset of DO data collected from Suisun Marsh (summer 2010) to evaluate the extent to which there might be potential for impairment. Based on these data, DO fell below 2 mg/L on several occasions, suggesting that there was potential for acute toxicity during these events. With respect to the potential for chronic effects, DO concentrations fell below 5 mg/L on a relatively frequent basis during June and July, suggesting that growth of sensitive species could be impaired. In addition to the CMC and CCC, USEPA procedures also allow for calculating the potential adverse effects of hypoxia on the survival of early life stages of fish and invertebrates. This approach is based on a Final Recruitment Concentration (FRC) that is intended to protect the strength of a given year class (i.e., not individuals) over an extended period that encompasses multiple spawning events. While the FRC was developed for the nearshore waters of the East Coast, the underlying model is based on DO response curves and biological data for 9 species that include 7 taxa that are either: 1) present in the Marsh as introduced species; or 2) represent genus or family-level surrogates of species that are present in the Marsh. Consequently, the model is relevant to Suisun Marsh. Notably, when the subset of DO data from Suisun Marsh (i.e., summer 2010) was evaluated against the FRC, the results suggested that there was potential for adverse effects on year-class strength. Overall, given that the example dataset represents very limited spatial and temporal coverage of the Marsh, the potential for adverse effects on survival, growth v and recruitment suggests that the extent of exceedances

should be evaluated on a broader scale. The calculated criteria represent what should be acceptable concentrations with respect to protecting against adverse effects of hypoxia. However, it is acknowledged that there is limited representation of local species in the data set and it may be desirable to develop and include data from additional locally relevant species in the calculation. That being said, given the breadth of taxa represented in the calculations, it is not likely that additional species would significantly alter the criteria values determined. In terms of implementing the criteria, it would be desirable to develop an assessment protocol that specifies the temporal/spatial averaging and data density necessary to make a determination of "impairment". Policy decisions on DO objectives should also take into account naturally-occurring seasonal, diurnal or tidally-influenced periods of low DO, and guidance will be needed regarding the use of DO objectives in the context of assessment, TMDLs and NPDES-permitting decisions.

CITATION

Bailey, H, C Curran, S Poucher, M Sutula. 2014. Science supporting dissolved oxygen objectives for Suisun Marsh. Technical Report 830. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0830
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/830_SuisunBay_web.pdf

Modeling in support of management of coastal hypoxia and acidification in the California Current ecosystem

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ABSTRACT

The U.S. West Coast has experienced an increasing number of hypoxia/acidification events severe enough to affect coastal marine ecosystems. The primary drivers for this trend are processes that operate at a global scale, but there are several management actions that can be taken at the regional scale to either reduce the rate of hypoxia/acidification or lessen the effects of these events on the coastal marine ecosystem. Determining the likely effectiveness of regional management actions requires coupled biogeochemical and physical circulation models that presently don't exist for near coastal environments. Furthermore, it is not even clear whether the types of data necessary to calibrate and validate such models with adequate accuracy to support management action are available. Moreover, funding for model development is often siloed by topic (e.g., hypoxia, acidification, harmful algal blooms) or region, with a lack of interregional and interdisciplinary studies directed at linking management across the West Coast.

To stimulate development of models that address hypoxia/acidification management needs, a two-day workshop involving state and federal managers, industry representatives and leading academic researchers was held in Costa Mesa, California on December 10 - 11, 2013. The workshop featured two breakout sessions in which participants were tasked to identify the most significant impediments to developing models and to create a prioritized list of actions to overcome these impediments while focusing on two management questions:

1) What is the relative contribution of local anthropogenic nutrient inputs to coastal hypoxia and acidification?

2) What geographic locations are the most susceptible to hypoxia and acidification?

The participants reconvened in a general assembly at the conclusion of each of the breakout sessions to summarize discussions and form consensus regarding conclusions. The workshop ended with a plenary discussion to coalesce the workshop's primary findings and recommendations.

Significant workshop findings and recommendations

The workshop produced two major findings:

The participants concluded that there are no significant technical impediments to developing models that will answer both management questions. However, answering these questions will require investment of resources. Still, calibration data are available and preliminary modeling has been conducted for several coastal regions. These data and modeling efforts can be used to provide preliminary information about the importance of local anthropogenic nutrient inputs to hypoxia/acidification managers and guide future expenditures of resources to address these questions in other regions.

The question of regional susceptibility to hypoxia/acidification events is more challenging and will require more investment to answer than the question about anthropogenic nutrient inputs. Workshop participants recommended focusing on the nutrient question, as the actions needed to address the question of the importance of local anthropogenic inputs will ultimately improve the modeling baseline needed to answer the susceptibility question.

Based on these conclusions, the workshop participants agreed there is a logical set of actions that should be conducted, the most prominent of which are:

• Build a community of modelers, observational researchers, and managers that: 1) encourages dialog among sectors about model outputs necessary to address management endpoints and underlying policy decisions, 2) facilitates discussion about the level of model validation needed for making management decisions, and 3) serves as a vehicle for coordination of modeling products among different technical specialists. Participants noted a lack of clarity about the management decision endpoints that this interaction forum would help clarify as interim products were developed, and ensure cost-effective allocation of modeling and data collection activities.

• Use existing models to begin bounding the problem. This is best done through a model comparison. There are

multiple approaches for addressing these questions and a comparison of outcomes from different approaches would provide multiple lines of evidence that constrain uncertainty in the answer. This model comparison should be conducted in a focused geographical region(s) and based on shared observational records and specific statistical measures that could be used to test various models. This comparison should be collaborative and ideally lead to integrated approaches.

• Collect observational data to support model refinement, including observations of oceanic state for model validation and short-duration, intensive monitoring to constrain key biogeochemical rate processes. This should go in tandem with a central repository for observational data and model output to provide open access and encourage research community participation.

Workshop participants also stressed the need for sustained research funding for basic science, including modeling, observational, and experimental studies to investigate the factors driving hypoxia/acidification events and their ecological effects.

CITATION

Sutula, M, M Howard, L Crowder, S McAfee. 2014. Modeling in support of management of coastal hypoxia and acidification in the California Current ecosystem. Technical Report 829. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0829
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/829_HypoxiaAcidification.pdf

Contaminants of Emerging Concern

SCCWRP Accomplishments

Contaminants of emerging concern (CECs) refer to the tens of thousands of chemicals that may be introduced to receiving waters through human activity that environmental managers are working to detect, understand and monitor. Although the knowledge base is limited, scientists are continually learning more about CECs' sources, pervasiveness and effects. With so many chemicals to triage, the traditional approach of monitoring and regulating individual chemicals has become unwieldy and obsolete. Moreover, ongoing changes in human activity have made CECs a moving target, with new chemicals continually being substituted for ones being phased out. Recognizing the need for a new approach to monitoring and assessment of environmental contaminants, SCCWRP has been working to develop novel methods to more widely and efficiently screen for CECs. The agency also is invested in building models to predict the impacts of high-priority CECs, to characterize key exposure routes, and to connect screening-level monitoring data to higher-level biological responses.

Unlike with historically regulated chemicals, the potential for impacts with CECs occurs at much lower levels and is manifested over longer periods of time. Consequently, SCCWRP has pursued development of a suite of chemical and biological tools to improve CEC monitoring. Chemical monitoring methods are necessary in characterizing the likelihood that humans and aquatic life will be exposed to harmful substances in the aquatic environment. Biological monitoring methods, meanwhile, are key to determining whether existing levels of chemical exposure are causing adverse impacts to wildlife and humans. SCCWRP's biological-monitoring focus is on adapting bioanalytical tools – which employ state-of-the-art engineered cell biology techniques – to screen receiving water bodies for thousands of chemicals at the same time; the goal is to make monitoring more efficient, relevant and comprehensive than the status quo (i.e. a chemical-by-chemical approach). To interpret biological-monitoring results, SCCWRP is pursuing development of chemical techniques that can identify the CECs responsible for exerting toxicity, a process known as non-targeted chemical analysis. Integration of these tools into a tiered monitoring framework will allow managers to make informed decisions concerning the level of treatment, discharge and occurrence of CECs.

Over the past year, SCCWRP has been working to adapt cellular bioassay technology and non-targeted chemical analysis for use in water-quality monitoring and assessment. With the progress demonstrated by these efforts, SCCWRP has been able to develop and vet an overall CEC strategy that will guide its research agenda over the next several years. Accomplishments in 2014 include:

» **Using bioanalytical screening to monitor endocrine-disrupting chemicals (EDCs) in recycled water:** SCCWRP and its collaborators have developed a simple screening method to test recycled wastewater for the presence of endocrine-disrupting chemicals (EDCs), paving the way for improved monitoring of chemicals known to interfere with growth, development and reproduction. This cell-based method, adapted from technology developed by the U.S. Environmental Protection Agency, is being considered by California for monitoring recycled water for the presence of residual EDCs. The SCCWRP-led study, set to be published in 2015, showed that the cell bioassay could correctly identify samples of high, intermediate and poor water quality, and that this standardized bioassay was reproducible in the hands of research lab personnel. Before this technology can be transferred to utility and commercial-services labs, SCCWRP and its collaborators must facilitate training and coordinating round-robin exercises to ensure comparability of monitoring results.

» **Identifying contaminants in marine mammals with non-targeted analysis:** A study examining exposure of Southern California marine mammals to anthropogenic chemicals has found that hundreds of distinct chemicals have accumulated in the bodies of these animals. SCCWRP and its university and government collaborators used non-targeted analytical techniques to assess the exposure levels of cetaceans found stranded along the Southern California coast, concluding, among other things, that dolphins hugging the coastline were exposed to a different suite of chemicals than marine mammals living further offshore. Most of the chemicals found in these animals are not routinely monitored, the study concluded. The study will help environmental managers to evaluate which pollutants should be prioritized for future monitoring, particularly as researchers learn more about the sources and potential effects of these unmonitored chemicals. Also, the non-targeted analytical method used in this study can now be applied more broadly to, for example, contaminated sediments and other forms of aquatic and marine life.

» **Designing a pilot study to monitor for CECs statewide:** SCCWRP has finalized the design of a multi-year pilot study that will allow California to begin monitoring for CECs in receiving waters statewide. A final report outlining the scope of the monitoring study is being released in 2015; the study itself is expected to take five years and will provide California with its first geographically diverse snapshot of the prevalence and impacts of CECs on the environment. The design was based

on recommendations from a statewide CEC expert advisory panel convened by SCCWRP in 2010. The panel previously developed CEC monitoring recommendations for recycled water; the State Water Board adopted those recommendations in 2013.

Which coastal and marine environmental contaminants are truly emerging?

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Abstract

To better understand the past and present impact of contaminants of emerging concern (CECs) in coastal and marine ecosystems, archived samples were analyzed for a broad suite of analytes, including pharmaceuticals and personal care products (PPCPs), flame retardants (including PBDEs), perfluorinated compounds (PFCs), and current-use pesticides. Surface sediment, mussels (*Mytilus* spp.) and sediment core samples collected from the California (USA) coast were obtained from environmental specimen banks. Selected CECs were detected in recent surface sediments, with nonylphenol (4-NP), its mono- and di-ethoxylates (NP1EO and NP2EO), triclocarban, and pyrethroid insecticides in the greatest abundance. Alkylphenols, triclocarban, and triclosan were present in sediment core segments from the 1970s, as well as in *Mytilus* tissue collected during the 1990s. Increasing concentrations of some CECs (e.g., miconazole, triclosan) were observed in the surface layers (ca. 2007) of a sediment core, in contrast to peak concentrations of 4-NP and triclocarban corresponding to input during the 1970s, and an apparent peak input for PBDEs during the 1990s. These results suggest that chemicals sometimes referred to as "emerging" (e.g., alkylphenols, triclocarban) have been present in the aquatic environment for several decades and are decreasing in concentration, whereas others (e.g., miconazole, triclosan) are increasing.

Citation

Maruya, KA, NG Dodder, CL Tang, W Lao, D Tsukada. 2014. Which coastal and marine environmental contaminants are truly emerging? *Environmental Science and Pollution Research* doi:10.1007/s11356-014-2856-1.

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Biological responses of marine flatfish exposed to municipal wastewater effluent

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Abstract

There is increasing concern over the presence of pharmaceutical compounds, personal care products, and other chemicals collectively known as contaminants of emerging concern (CECs) in municipal effluents, yet knowledge of potential environmental impacts related to these compounds is still limited. The present study used laboratory exposures to examine estrogenic, androgenic, and thyroid-related endocrine responses in marine hornyhead turbot (*Pleuronichthys verticalis*) exposed to CECs from municipal effluents with 2 degrees of treatment. Fish were exposed for 14 d to environmentally realistic concentrations of effluent (0.5%) and to a higher concentration (5%) to investigate dose responses. Plasma concentrations of estradiol (E2), vitellogenin (VTG), 11-ketotestosterone, and thyroxine were measured to assess endocrine responses. Contaminants of emerging concern were analyzed to characterize the effluents. Diverse types of effluent CECs were detected. Statistically significant responses were not observed in fish exposed to environmentally realistic concentrations of effluent. Elevated plasma E2 concentrations were observed in males exposed to ammonia concentration similar to those found in effluents. However, exposure to ammonia did not induce VTG production in male fish. The results of the present study highlight the importance of conducting research with sentinel organisms in laboratory studies to understand the environmental significance of the presence of CECs in aquatic systems.

Citation

Vidal-Dorsch, DE, SM Bay, DJ Greenstein, ME Baker, G Hardiman, JA Reyes, KM Kelley, D Schlenk. 2013. Biological responses of marine flatfish exposed to municipal wastewater effluent. *Environmental Toxicology and Chemistry* 33:583-591. doi:10.1002/etc.2466.

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Gene networks and toxicity pathways induced by acute cadmium exposure in adult largemouth bass (Micropterus salmoides)

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Abstract

Cadmium is a heavy metal that can accumulate to toxic levels in the environment leading to detrimental effects in animals and humans including kidney, liver and lung injuries. Using a transcriptomics approach, genes and cellular pathways affected by a low dose of cadmium were investigated. Adult largemouth bass were intraperitoneally injected with 20 µg/kg of cadmium chloride (mean exposure level – 2.6 µg of cadmium per fish) and microarray analyses were conducted in the liver and testis 48 h after injection. Transcriptomic profiles identified in response to cadmium exposure were tissue-specific with the most differential expression changes found in the liver tissues, which also contained much higher levels of cadmium than the testis. Acute exposure to a low dose of cadmium induced oxidative stress response and oxidative damage pathways in the liver. The mRNA levels of antioxidants such as catalase increased and numerous transcripts related to DNA damage and DNA repair were significantly altered. Hepatic mRNA levels of metallothionein, a molecular marker of metal exposure, did not increase significantly after 48 h exposure. Carbohydrate metabolic pathways were also disrupted with hepatic transcripts such as UDP-glucose, pyrophosphorylase 2, and sorbitol dehydrogenase highly induced. Both tissues exhibited a disruption of steroid signalling pathways. In the testis, estrogen receptor beta and transcripts linked to cholesterol metabolism were suppressed. On the contrary, genes involved in cholesterol metabolism were highly increased in the liver including genes encoding for the rate limiting steroidogenic acute regulatory protein and the catalytic enzyme 7-dehydrocholesterol reductase. Integration of the transcriptomic data using functional enrichment analyses revealed a number of enriched gene networks associated with previously reported adverse outcomes of cadmium exposure such as liver toxicity and impaired reproduction.

Citation

Mehinto, AC, MS Prucha, RC Colli-Dula, KJ Kroll, CM Lavelle, DS Barber, CD Vulpe, ND Denslow. 2014. Gene networks and toxicity pathways induced by acute cadmium exposure in adult largemouth bass (*Micropterus salmoides*). *Aquatic Toxicology* 152C:186-194. doi:10.1016/j.aquatox.2014.04.004.

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Benchmarking organic micropollutants in wastewater, recycled water and drinking water with in vitro bioassays

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Abstract

Thousands of organic micropollutants and their transformation products occur in water. Although often present at low concentrations, individual compounds contribute to mixture effects. Cell-based bioassays that target health-relevant biological endpoints may therefore complement chemical analysis for water quality assessment. The objective of this study was to evaluate cell-based bioassays for their suitability to benchmark water quality and to assess efficacy of water treatment processes. The selected bioassays cover relevant steps in the toxicity pathways including induction of xenobiotic metabolism, specific and reactive modes of toxic action, activation of adaptive stress response pathways and system responses. Twenty laboratories applied 103 unique in vitro bioassays to a common set of 10 water samples collected in Australia, including wastewater treatment plant effluent, two types of recycled water (reverse osmosis and ozonation/activated carbon filtration), stormwater, surface water, and drinking water. Sixty-five bioassays (63%) showed positive results in at least one sample, typically in wastewater treatment plant effluent, and only five (5%) were positive in the control (ultrapure water). Each water type had a characteristic bioanalytical profile with particular groups of toxicity pathways either consistently responsive or not responsive across test systems. The most responsive health-relevant endpoints were related toxenobiotic metabolism (pregnane X and aryl hydrocarbon receptors), hormone-mediated modes of action (mainly related to the estrogen, glucocorticoid, and antiandrogen activities), reactive modes of action (genotoxicity) and adaptive stress response pathway (oxidative stress response). This study has demonstrated that selected cell-based bioassays are suitable to benchmark water quality

and it is recommended to use a purpose-tailored panel of bioassays for routine monitoring.

Citation

Escher, BI, M Allinson, R Altenburger, PA Bain, P Balaguer, W Busch, J Crago, ND Denslow, E Dopp, K Hilscherova, AR Humpage, A Kumar, M Grimaldi, BS Jayasinghe, B Jarosova, A Jia, S Makarov, KA Maruya, A Medvedev, AC Mehinto, JE Mendez, A Poulsen, E Prochazka, J Richard, A Schifferli, D Schlenk, S Scholz, F Shiraishi, S Snyder, G Su, JYM Tang, B van der Burg, SC van der Linden, I Werner, SD Westerheide, CKC Wong, M Yang, BHY Yeung, X Zhang, FDL Leusch. 2013. Benchmarking organic micropollutants in wastewater, recycled water and drinking water with in vitro bioassays. *Environmental Science & Technology* 48:1940–1956.

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Molecular analysis of endocrine disruption in hornyhead turbot at wastewater outfalls in Southern California using a second generation multi-species microarray

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Abstract

Sentinel fish hornyhead turbot (*Pleuronichthys verticalis*) captured near wastewater outfalls are used for monitoring exposure to industrial and agricultural chemicals of ~20 million people living in coastal Southern California. Although analyses of hormones in blood and organ morphology and histology are useful for assessing contaminant exposure, there is a need for quantitative and sensitive molecular measurements, since contaminants of emerging concern are known to produce subtle effects. We developed a second generation multi-species microarray with expanded content and sensitivity to investigate endocrine disruption in turbot captured near wastewater outfalls in San Diego, Orange County and Los Angeles California. Analysis of expression of genes involved in hormone [e.g., estrogen, androgen, thyroid] responses and xenobiotic metabolism in turbot livers was correlated with a series of phenotypic end points. Molecular analyses of turbot livers uncovered altered expression of vitellogenin and zona pellucida protein, indicating exposure to one or more estrogenic chemicals, as well as, alterations in cytochrome P450 (CYP) 1A, CYP3A and glutathione S-transferase-α indicating induction of the detoxification response. Molecular responses indicative of exposure to endocrine disruptors were observed in field-caught hornyhead turbot captured in Southern California demonstrating the utility of molecular methods for monitoring environmental chemicals in wastewater outfalls. Moreover, this approach can be adapted to monitor other sites for contaminants of emerging concern in other fish species for which there are few available gene sequences.

Citation

Baker, ME, DE Vidal-Dorsch, C Ribecco, LJ Sprague, M Angert, N Lekmine, C Ludka, A Martella, E Ricciardelli, SM Bay, JR Gully, KM Kelley, C Schlenk, O Carnevali, R Sasik, G Hardiman. 2013. Molecular analysis of endocrine disruption in hornyhead turbot at wastewater outfalls in Southern California using a second generation multi-species microarray. *PLoS ONE* 8:e75553.

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Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/783_MolecularAnalysis.pdf

BIOASSESSMENT

SCCWRP Accomplishments

Biological assessment, or bioassessment, is the science of evaluating the health of an ecosystem by assessing the organisms that live within it. In aquatic ecosystems, algae and marine and freshwater invertebrates serve as particularly useful indicators of ecosystem health because they are relatively sessile and live along bottom habitats where chemical and other stressors tend to be concentrated. Unlike traditional chemistry-based monitoring, which provides only limited information about a relatively narrow portion of the environment at a discrete point in time, bioassessment can account for living organisms exposed to multiple chemicals and other stressful factors (such as altered habitats and changes in life-sustaining water-flow patterns) over extended time periods as they move through an ecosystem. Consequently, bioassessment has the potential to provide a more integrated reflection of the condition of an aquatic ecosystem; bioassessment also is more closely tied to environmental managers' end-goal focus on ecosystem protection and serves as an important way to monitor and protect the populations of endangered species and fisheries. SCCWRP is focused on developing bioassessment tools that environmental managers can use to accurately assess the health of aquatic ecosystems and can readily interpret to inform regulatory and management decisions. SCCWRP has made considerable progress on developing bioassessment tools for streams, wetlands and nearshore marine environments that rely primarily on evaluating the health of benthic invertebrates and algae. SCCWRP's ultimate goal is to develop bioassessment tools for all aquatic habitats using a variety of organisms, as different organisms are uniquely suited to evaluate specific habitats.

SCCWRP's bioassessment work revolves around two main research areas: (1) developing and refining scoring tools that aquatic managers can use to translate complex information on the health of biological communities into actionable information, and (2) developing ways to understand and interpret the likely causes of observed biological impacts, so aquatic managers can take appropriate actions. The scoring tools being developed by SCCWRP, commonly known as indices, take vast sums of ecosystem data and simplify them into a single number that corresponds to the degree of environmental impact. The best-designed bioassessment indices can discern ecosystem changes associated with natural variation from changes associated with anthropogenic stress; ideally, indices also should provide insight into specific stressors that may be associated with observed biological changes. SCCWRP's approach to building bioassessment indices falls into four distinct stages of development: (1) SCCWRP begins by defining the minimally disturbed reference conditions that provide a basis for comparisons of assessment tools. Reference conditions must represent the natural range of conditions expected to occur at sites with minimal human-caused disturbance. (2) SCCWRP develops scoring tools that translate different measures of community composition into simple indices. These tools may be based on measures of the diversity, composition or function of the biological community. (3) SCCWRP uses an approach known as causal assessment to interpret the reason for less-than-desired biological index scores and to identify potential stressors that should be prioritized for management. Causal assessment can rely on any combination of biological, molecular, chemical or toxicological evaluation. (4) SCCWRP develops frameworks and capacity for implementation of bioassessment tools into management and monitoring programs. These may take the form of decision-support systems, case studies, automated analytical tools, training programs and data-management systems.

Although progress has been made at all four stages of bioassessment tool development, SCCWRP's primary progress in 2014 was on developing new and improved scoring tools. SCCWRP produced new scoring tools for wadeable streams, developed tools for non-perennial streams that had been omitted from past surveys because of lack of tools, and advanced efforts to develop molecular methods for bioasseessment. SCCWRP also made significant progress developing additional causal-assessment tools over the past year and expects to introduce substantial new products in 2015. Accomplishments in 2014 include:

» **Developing new scoring tools for wadeable streams:** SCCWRP has released two new bioassessment scoring tools that represent important steps forward in environmental managers' ability to more accurately assess California's wadeable stream ecosystems. The California Stream Condition Index uses the health of benthic invertebrates to evaluate the state's wadeable streams via a predictive approach. Because this index provides a substantially larger reference network that allows any California wadeable stream to be assessed relative to modeled reference expectations for comparable stream types, the same scoring tool can be used for all wadeable streams in the state; this index has obviated the need for region-specific indices and paved the way for development of consistent statewide standards for assessing stream health. SCCWRP also has released California's first-ever indices of biotic integrity (IBIs) for algae, providing a complementary indicator to existing benthic-invertebrate indices and thus allowing for more robust assessment of the condition of in-stream biological

communities. The algal indices were produced for diatoms, soft algae and a hybrid algae with the characteristics of both diatoms and soft algae.

» **Predicting flow patterns for Southern California's non-perennial streams:** SCCWRP has demonstrated that a new bioassessment tool designed to evaluate the health of California's constantly flowing streams can be effectively applied to non-perennial streams as well, greatly expanding the utility of the tool. The California Stream Condition Index tool, which relies on a predictive approach to assess the health of benthic invertebrates in streams, was originally designed by SCCWRP and its partners for use with perennial streams (i.e., streams that flow throughout the year). Researchers weren't sure if the California Stream Condition Index also could be used to assess non-perennial streams; one hypothesis was that the index would conclude habitat degradation every time a non-perennial stream went dry due to natural, cyclical processes. In the SCCWRP-led study, published in 2014, researchers showed that the index worked well across a gradient of non-perennial stream conditions. The finding was particularly significant because an earlier 2014 study found that non-perennial streams are the predominant stream type in Southern California. In one region studied – San Diego – 85% of streams were predicted to be dry by May, even during particularly wet years.

» **Augmenting bioassessments with DNA technology:** SCCWRP and its collaborators have demonstrated that analyzing the DNA of benthic macroinvertebrates during a stream bioassessment improves scientists' ability to detect subtle changes in ecosystem health. During the study, which was published in 2014, researchers tested the utility of using genetic DNA markers from the bottom-dwelling organisms to identify which species were present in the stream; this molecular approach, known as DNA barcoding, was then compared to using standard microscopy to identify the same species. The molecular method allowed scientists to detect several key taxa – including midges, mayflies, caddisflies and black flies – that standard microscopy could not. The study showed that this molecular approach could be a powerful, cost-effective tool in bioassessment, with the potential to provide data much faster than microscopy-identification methods.

Effect of ecological group classification schemes on performance of the AMBI benthic index in U.S. coastal waters

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ABSTRACT

The AZTI Marine Biotic Index (AMBI) requires less geographically-specific calibration than other benthic indices, but has not performed as well in U.S. coastal waters as it has in the European waters for which it was originally developed. Here we examine the extent of improvement in index performance when the Ecological Group (EG) classifications on which AMBI is based are derived using local expertise. Twenty-three U.S. benthic experts developed EG scores for each of three regions in the United States, as well as for the U.S. as a whole. Index performance was then compared using: (1) EG scores specific to a region, (2) national EG scores, (3) national EG scores supplemented with standard international EG scores for taxa that the U.S. experts were not able to make assignments, and (4) standard international EG scores. Performance of each scheme was evaluated by diagnosis of condition at pre-defined good/bad sites, concordance with existing local benthic indices, and independence from natural environmental gradients. The AMBI performed best when using the national EG assignments augmented with standard international EG values. The AMBI using this hybrid EG scheme performed well in differentiating apriori good and bad sites (>80% correct classification rate) and AMBI scores were both concordant and correlated (rs = 0.4–0.7) with those of existing local indices. Nearly all of the results suggest that assigning the EG values in the framework of local biogeographic conditions produced a better-performing version of AMBI. The improved index performance, however, was tempered with apparent biases in score distribution. The AMBI, regardless of EG scheme, tended to compress ratings away from the extremes and toward the moderate condition and there was a bias with salinity, where high quality sites

received increasingly poorer condition scores with decreasing salinity.

CITATION

Gillett, DJ, SB Weisberg, T Grayson, A Hamilton, V Hansen, EW Leppo, MC Pelletier, A Borja, D Cadien, D Dauer, R Diaz, M Dutch, JL Hyland, M Kellogg, PF Larsen, JS Levinton, R Llansó, LL Lovell, PA Montagna, D Pasko, CA Phillips, C Rakocinski, JA Ranasinghe, DM Sanger, H Teixeira, RF Van Dolah, RG Velarde, KI Welch. 2015. Effect of ecological group classification schemes on performance of the AMBI benthic index in U.S. coastal waters. *Ecological Indicators* 50:99-107.

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Is DNA barcoding actually cheaper and faster than traditional morphological methods? Results from a survey of freshwater bioassessment efforts in the United States

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ABSTRACT

Taxonomic identification accounts for a substantial portion of cost associated with bioassessment programs across the United States. New analytical approaches, such as DNA barcoding, have been promoted as a way to reduce monitoring costs and improve efficiency, yet this assumption has not been thoroughly evaluated. We address this question by comparing costs for traditional morphology-based bioassessment, the standard Sanger sequencing-based DNA barcoding approach, and emerging next-generation (NGS) molecular methods. Market demand for molecular approaches is also assessed through a survey of the level of freshwater bioassessment effort in the United States across multiple habitat types (lakes, streams, wetlands) and indicators (benthic invertebrates, fish, algae). All state and regional level programs administered by public agencies and reported via agency websites were included in the survey. Costs were based on surveys of labs and programs willing to provide such information. More than 19,500 sites are sampled annually across the United States, with the majority of effort occurring in streams. Benthic invertebrates are the most commonly used indicator, but algae and fish comprise between 35% and 21% of total sampling effort, respectively. We estimate that between $104 and $193 million is spent annually on routine freshwater bioassessment in the United States. Approximately 30% of the bioassessment costs are comprised of the cost to conduct traditional morphology-based taxonomy. Current barcoding costs using Sanger sequencing are between 1.7 and 3.4 times as expensive as traditional taxonomic approaches, excluding the cost of field sampling (which is common to both approaches). However, the cost of NGS methods are comparable (or slightly less expensive) than traditional methods depending on the indicator. The promise of barcoding as a cheaper alternative to current practices is not yet realized, although molecular methods may provide other benefits, such as a faster sample processing and increased taxonomic resolution.

CITATION

Stein, ED, MC Martinez, S Stiles, PE Miller, EV Zakharov. 2014. Is DNA barcoding actually cheaper and faster than traditional morphological methods? Results from a survey of freshwater bioassessment efforts in the United States. *PLoS ONE* 9:e95525. doi:10.1371/journal.pone.0095525.

SCCWRP Journal Article #0823
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/823_IsBarcodingCheaper.pdf

Cryptic biodiversity in streams: A comparison of macroinvertebrate communities based on morphological and DNA barcode identifications

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ABSTRACT

Species-level identifications are difficult or impossible for many larval aquatic macroinvertebrates. We described the taxonomic composition of macroinvertebrate communities from 5 coastal streams in 3 neighboring catchments in southern California. We compared taxonomic identifications based on deoxyribonucleic acid (DNA) barcoding (cytochrome c oxidase subunit I [COI]) with morphological identifications of the same specimens. We examined 5870 individuals, and barcodes with sequence lengths >350 base pairs (bp) for 91% of those specimens. We used the naturally occurring gaps in divergence frequencies for each order (usually 2% level of genetic divergence) to delimit putative species for all taxonomic groups except Simulium (3%) and Baetis (1%). We identified 200 species across these 5 streams. We identified 104 more species via barcodes than via morphology (200 vs 96, a 108% increase). Richness increases were greatest for Chironomidae (60 more species), Ephemeroptera (10 species), Acari (10 species), and Trichoptera (6 species). Forty-five percent of the genera/species identified morphologically represented >2 species. Many (86) species identified with barcodes were represented by only 1 or 2 specimens and were found at only 1 stream. Thus, species rarity (either spatially or numerically) appears to be a common characteristic of these streams. Barcoding increased total richness at each site by 12 to 40 taxa over morphology alone, and increased the difference between reference and impact sites in terms of lost taxa. These results suggest that macroinvertebrate biodiversity in streams has been underestimated substantially in the past, as has the biodiversity lost in response to environmental stress. The potential of DNA barcoding will not be fully realized until we can assign traits,

such as habitat preference, ecological function, and pollution tolerance, at the species level.

CITATION

Jackson, JK, JM Battle, BP White, EM Pilgrim, ED Stein, PE Miller, BW Sweeney. 2014. Cryptic biodiversity in streams: A comparison of macroinvertebrate communities based on morphological and DNA barcode identifications. *Freshwater Science* 33:312-324. doi:10.1086/675225.

SCCWRP Journal Article #0811
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/811_CrypticBiodiversityInStreams.pdf

Identifying reference conditions and quantifying biological variability within benthic macroinvertebrate communities in perennial and non-perennial Northern California streams

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ABSTRACT

Identification of minimally disturbed reference sites is a critical step in developing precise and informative ecological indicators. We tested procedures to select reference sites, and quantified natural variation (inter-site and -annual variability) among reference conditions using a macroinvertebrate data set collected from 429 mediterranean- climate stream reaches in the San Francisco Bay Area, California (USA). We determined that a landscape GIS-based stressor screen followed by a local field-based stressor screen effectively identified least-disturbed reference sites that, based on NMS ordination results, supported different biological communities than sites identified with only landscape (GIS) or local (field) stressors. An examination of least-disturbed reference sites indicated that intersite variability was strongly associated with stream hydrology (i.e., perennial vs. non-perennial flow) and annual precipitation, which highlights the need to control for such variation when developing biological indicators through natural gradient modeling or using unique biological indicators for both non-perennial and perennial streams. Metrics were more variable among non-perennial streams, indicating that additional modeling may be needed to develop precise biological indicators for non-perennial streams. Among 192 sites sampled two to six times over the 8-year study period, the biological community showed moderate inter-annual variability, with the 100 point index of biotic integrity scores varying from 0 to 51 points (mean = 11.5). Variance components analysis indicated that inter-annual variability explained only a fraction (5–18 %) of the total variation when compared against sitelevel variation; thus efforts to understand causes of natural variation between sites will produce more precise and accurate biological indicators.

CITATION

Lunde, KB, MR Cover, RD Mazor, CA Sommers, VH Resh. 2013. Identifying reference conditions and quantifying biological variability within benthic macroinvertebrate communities in perennial and non-perennial Northern California streams. *Environmental Management* 51:1262-1273.

SCCWRP Journal Article #0766
Full text available by request: pubrequest@sccwrp.org

Benthic macrofaunal assemblages of the San Francisco Estuary and Delta, USA

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ABSTRACT

The spatial and temporal distribution of macrobenthic assemblages in the San Francisco Estuary and Sacramento–San Joaquin River Delta were identified using hierarchical cluster analysis of 501 samples collected between 1994 and 2008. Five benthic assemblages were identified that were distributed primarily along the salinity gradient: (1) a polyhaline assemblage that inhabits the Central Bay, (2) a mesohaline assemblage that inhabits South Bay and San Pablo Bay, (3) a low-diversity oligohaline assemblage primarily in Suisun Bay, (4) a low-diversity sand assemblage that occurs at various locations throughout the Estuary, and (5) a tidal freshwater assemblage in the Delta. Most sites were classified within the same assemblage in different seasons and years, but a few sites switched assemblage designations in response to seasonal changes in salinity from freshwater inflows.

CITATION

Thompson, B, JA Ranasinghe, S Lowe, A Melwani, SB Weisberg. 2013. Benthic macrofaunal assemblages of the San Francisco Estuary and Delta, USA. *Environmental Monitoring and Assessment* 185:2281-2295.

SCCWRP Journal Article #0751
Full text available by request: pubrequest@sccwrp.org

Characterization of the rocky intertidal ecological communities associated with Southern California Areas of Special Biological Significance: Phase II

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ABSTRACT

Two phases of sampling were done to characterize the biological communities at sites near to discharges in ASBS and at reference sites (considered to be unaffected by discharges). Sites were arranged in six geographic groups to account for biogeographical patterns in species composition. In Phase I, we concluded, “While there was no indication of a general and similar impact of discharges on

biological communities there was an indication that specific locations might be affected by compromised water quality." In fact, one of the motivations for Phase II sampling was to determine if those sites that showed biological communities potentially affected by discharge showed the same pattern in the later sampling period. Using an analytical approach designed to assess site-specific effects, we found that there was no evidence of "persistent" effects and that the likely explanation was natural (or at least not related to discharge) variability in biological communities. None of the four sites that exceeded the prediction limits in Phase I exceed them in Phase II. Consistent with the idea of temporal variation, we found that three sites in Phase II exceeded the prediction limits and none of the three exceeded them in Phase 1 (Note that one, Muddy Canyon, was not evaluated in Phase I). These results point to the strength of the phased assessment, particularly with respect to the possibility of an uninformed conclusion of discharge related effects. No matter how carefully a survey is designed, there is no way to completely control for the contributions of extraneous factors. In such situations it is often useful to examine if patterns hold over time – as was done here.

CITATION

Raimondi, P. 2014. Characterization of the rocky intertidal ecological communities associated with Southern California Areas of Special Biological Significance: Phase II. Technical Report 818. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0818
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/818_ASBSRockyIntertidal.pdf

Sediment Quality

SCCWRP Accomplishments

The quality of sediment that underlies water bodies is a sentinel indicator of the health of marine ecosystems. Pollutants flushed down drains and discharged from urban watersheds have led to sediment contamination along California's coastline, with contamination levels most acute in bays and estuaries, where slower-flowing waters promote settling of contaminant-laden particles. SCCWRP has been at the forefront of efforts to quantify, monitor and develop solutions to remediate contaminated sediment. In partnership with its collaborators, SCCWRP has advanced sediment-quality science into the regulatory arena through the development of a carefully calibrated, rigorously vetted assessment framework that gauges the impacts of sediment contamination on the bottom-dwelling organisms that come into contact with it. In California, this assessment framework has become the technical foundation for implementing the state's Sediment Quality Objectives program that went into effect in 2009. SCCWRP also has advanced its research agenda to investigate the flip side of sediment contamination, developing sophisticated mathematical models that quantify how contamination from sediment moves through the food web and bioaccumulates in seafood consumed by humans.

At SCCWRP, researchers are studying the two main ways that organisms become exposed to sediment contamination: direct exposure, where bottom-dwelling marine life come into contact with and ingest contamination in sediment, and indirect exposure, where predators accumulate toxins in their bodies as they consume contaminated prey. Each exposure route requires a different conceptual approach to build a comprehensive assessment framework that can accurately measure and estimate the impacts of sediment contamination on the organisms exposed to it, including humans. SCCWRP's ultimate goal is to build a common, agreed-upon technical foundation for assessing sediment quality to help water-quality managers make better-informed decisions about sediment remediation and cleanup activities.

Over the past year, SCCWRP has been pursuing research across both the direct-exposure and indirect-exposure arenas. These studies have helped push the boundaries for how environmental managers can more accurately and consistently assess sediment contamination, and also have painted a more detailed picture of the state of sediment contamination up and down California's coastline. Accomplishments in 2014 include:

» **Tracking sediment contamination in submarine canyons:** New analyses of sediment from the submarine canyons of the Southern California Bight indicate that about one-third of the sediment in these deep underwater trenches appears to be contaminated at levels toxic to sediment-dwelling organisms. The results, set to be published in summer 2015, mark the first time that the condition of canyon sediment has been assessed as part of the ongoing Southern California Bight Regional Monitoring Program, a nationally recognized, collaborative effort to gauge the health of Southern California Bight ecosystems. With this canyon data from the 2013 cycle of the Bight program, researchers have been able to get a clearer sense of how contaminated sediment from shallow coastal waters appears to be traveling via submarine canyons to deeper waters. Previous Bight monitoring data indicated that sediment in the slope – the transition zone between the mainland shelf and deep ocean waters – also had become contaminated; it just wasn't clear how it got there. As researchers continue Bight monitoring and data analysis, they expect to be able to determine whether sediment contamination levels in the canyons are higher or lower than those found in the slope, as well as to begin to address which specific areas along the coastline might be the sources of the sediment contamination.

» **Comparing state sediment framework to its federal counterpart:** Following adoption of California's Sediment Quality Objectives (SQO) program for coastal embayments in 2009, the state diverged from federal programs in defining how coastal sediment quality is assessed. This prompted researchers to ask an important question: Are results generated under the state SQO program comparable to results generated by federal sediment-quality assessment studies? SCCWRP answered this question in 2014 with successful completion of a comparison of state SQO results and federal results from the Environmental Protection Agency's most recent National Coastal Condition Assessment; the final report is scheduled to be published in 2015. Although the study concluded that the state and federal assessment frameworks did not yield matching results (more embayments were deemed impacted by sediment contamination using the federal sediment-quality index than the state SQO assessment method), SCCWRP learned how to adapt state SQO results for comparison at a national level, paving the way for California's SQO program to be effectively contextualized and applied at a much larger scale.

» **Evaluating sediment assessment framework for human health:** A newly developed framework intended to quantify the indirect human-health impacts of consuming contaminated seafood was subjected to its first large-scale demonstration test in 2014. Using data from six California embayments, SCCWRP applied the framework

to predict the health risk for people who consume seafood harvested from each of the embayments and the likelihood that contamination in this seafood originated in sediment. The framework, which has been about five years in the making, consists of a series of sophisticated mathematical models that must be adapted to site-specific situations and conditions; SCCWRP has been working with a stakeholder advisory committee to develop each of the assessment framework's three tiers.

The pilot study found that the human health framework yielded reasonable, accurate results. The findings and lessons learned will be incorporated into a guidance document that is expected to be released in 2016. This human health framework is eventually expected to be incorporated into California's SQO program, allowing the program to extend its reach beyond evaluating just the impacts on bottom-dwelling marine life.

Calculating the diffusive flux of persistent organic pollutants between sediments and the water column on the Palos Verdes Shelf Superfund Site using polymeric passive samplers

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ABSTRACT

Passive samplers were deployed to the seafloor at a marine Superfund site on the Palos Verdes Shelf, California, USA, and used to determine water concentrations of persistent organic pollutants (POPs) in the surface sediments and near-bottom water. A model of Fickian diffusion across a thin water boundary layer at the sediment-water interface was used to calculate flux of contaminants due to molecular diffusion. Concentrations at four stations were used to calculate the flux of DDE, DDD, DDMU, and selected PCB congeners from sediments to the water column. Three passive sampling materials were compared: PE strips, POM strips, and SPME fibers. Performance reference compounds (PRCs) were used with PE and POM to correct for incomplete equilibration, and the resulting POP concentrations, determined by each material, agreed within 1 order of magnitude. SPME fibers, without PRC corrections, produced values that were generally much lower (1 to 2 orders of magnitude) than those measured using PE and POM, indicating that SPME may not have been fully equilibrated with waters being sampled. In addition, diffusive fluxes measured using PE strips at stations outside of a pilot remedial sand cap area were similar to those measured at a station inside the capped area: 240 to 260 ng cm^{-2} y^{-1} for p,p′-DDE. The largest diffusive fluxes of POPs were calculated at station 8C, the site where the highest sediment concentrations have been measured in the past, 1100 ng cm^{-2} y^{-1} for p,p′-DDE.

CITATION

Fernandez, LA, W Lao, KA Maruya, RM Burgess. 2014. Calculating the diffusive flux of persistent organic pollutants between sediments and the water column on the Palos Verdes Shelf Superfund Site using polymeric passive samplers. *Environmental Science & Technology* 48:3925-3934. doi:10.1021/es404475c.

SCCWRP Journal Article #0819
Full text available by request: pubrequest@sccwrp.org

Passive sampling in contaminated sediment assessment: Building consensus to improve decision-making

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ABSTRACT

Contaminated sediments pose an ongoing, pervasive, global challenge to environmental managers as sediments can reflect a legacy of pollution that can impair the beneficial uses of water bodies. A formidable challenge in assessing the risks of contaminated sediments has been elucidation and measurement of contaminant bioavailability, expressed as the freely dissolved concentration (C_{free}) in interstitial water which serves as a surrogate measure of the substances' chemical activity. Recent advances in passive sampling methods (PSMs) enable C_{free} of sediment-associated contaminants to be quantified at trace levels thereby overcoming current limitations of predictive models. As a result, PSMs afford the opportunity for a paradigm shift from traditional practice that can effectively reduce uncertainty in risk assessment and bolster confidence in the science used to support management of contaminated sediments. This paper provides a brief overview of the five subsequent papers in this series that: review literature on PSM use in sediments for both organic and metal(loid) contaminants; outline the technical rationale for using PSMs as a preferred basis for risk assessment over conventional chemical analyses; describe practical considerations for and uncertainties associated with laboratory and field deployment of PSMs; discuss management application of PSMs including illustrative case studies where PSMs have been used in decision-making; and, highlight future research and communication needs.

CITATION

Parkerton, TF, KA Maruya. 2013. Passive sampling in contaminated sediment assessment: Building consensus to improve decision-making. *Integrated Environmental Assessment and Management* 10:163–166.

SCCWRP Journal Article #0796
Full text available by request: pubrequest@sccwrp.org

Regional assessment of marine and estuarine sediment toxicity in Southern California, USA

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[4]*Orange County Sanitation District, Environmental Laboratory & Ocean Monitoring, Fountain Valley, CA*

Abstract

Sediment toxicity was investigated at 222 stations in the Southern California Bight (SCB) during 2008. This represented the first time that assessment methods established by California's new Sediment Quality Objectives program were employed in a survey of this scale. The goal was to determine the extent and magnitude of sediment toxicity in the SCB, how toxicity compared among specific environments, and whether toxicity has changed over the last decade. Two toxicity tests were used: the 10-day amphipod whole sediment survival test with *Eohaustorius estuarius* and a 48-h embryo development test with the mussel *Mytilus galloprovincialis* exposed at the sediment–water interface. Less than 1% of the area of the SCB was found to be toxic to the amphipod test. No toxicity was found in offshore stations, but 14% of embayment areas were toxic to the amphipods. The mussel test identified 13% of the embayment areas to be toxic. Estuary and marina locations had the greatest areal extent of toxicity for both tests. The two toxicity methods agreed that sediments were not toxic at over half of the stations tested. The mussel test showed a greater magnitude of response than the amphipod. Sediment toxicity was shown to have declined in both extent and magnitude from levels measured in 1998 and 2003.

Citation

Greenstein, D, S Bay, M Jacobe, C Barton, K Sakamoto, D Young, K Ritter, K Schiff. 2013. Regional assessment of marine and estuarine sediment toxicity in Southern California, USA. *Environmental Monitoring and Assessment* 185:2055-2065.

SCCWRP Journal Article #0746
Full text available by request: pubrequest@sccwrp.org

Flow Ecology

SCCWRP Accomplishments

Flow ecology, the study of how changes in the flow of water can impact ecosystems, has historically focused on understanding the role that moving water plays in transporting and depositing pollutants. But the magnitude, duration and persistence of runoff from land surfaces can also trigger stream erosion and deposition, causing permanent physical and hydrologic changes that affect the ability of streams to support desired plant and animal communities. These changes, referred to as hydromodification, can result from both direct manipulation (e.g., diversion, impoundment, or discharge) and indirect effects (e.g., changes in land use). Traditional approaches have focused on predicting changes in water chemistry in response to specific anthropogenic actions, and on developing management measures – including best management practices (BMPs) – aimed at offsetting the effects of these chemical changes. Substantially less effort has been devoted to relating hydrologic and physical alterations to how biological communities respond to them. As regulatory programs increasingly rely on these biological endpoints to assess compliance and the effectiveness of mitigation efforts, SCCWRP has been working to develop and improve tools that can help environmental managers better understand and ultimately predict the relationship between flow (and its associated hydrologic and physical impacts) and ecosystem health. Better tools will better inform management actions for reducing and mitigating the impacts of flow alteration.

SCCWRP's flow ecology research is driven by three major objectives: (1) Develop tools to evaluate the relationship between changes in flow and related physical and biological responses in the stream. These tools may be in the form of statistical or deterministic models; separate tools are necessary to predict physical and biological effects. (2) Evaluate the effectiveness of various management actions (e.g., BMPs) and other efforts to reduce or mitigate the impacts of flow modification. This evaluation must include mechanisms that enhance performance and that improve understanding of how multiple BMPs can work together across broad areas to improve the condition of receiving waters. (3) Develop improved decision-support and data-visualization tools that can help translate complex hydro-physical-biological relationships into data that environmental managers can readily understand and use.

Over the past year, SCCWRP has focused its work around baseline studies of environmental flow effects that can support subsequent analysis, as well as hydromodification and BMP work that has centered around integrating tools into implementation programs. Accomplishments in 2014 include:

» **Paving the way to evaluate environmental flow effects in California's streams:** SCCWRP and its collaborators have developed a comprehensive classification system for grouping all of California's streams into seven categories based on expected flow characteristics under reference conditions, a critical step in laying the foundation to evaluate flow-ecology relationships for about 150,000 stream reaches statewide. The classification system is designed around offering scientists a spatial understanding of how flow regimes vary over time for all of California's rivers and regions, and how a stream's natural characteristics and setting influence the relationship between flow and biology. The seven classes were defined primarily by differences in winter precipitation, geology, and mean watershed elevation. Each of the seven classes also was analyzed to determine which flow variables best differentiate a stream in its minimally disturbed reference condition from non-reference conditions. Ten variables, most of which are associated with low flow conditions or flow recession, were identified as most important; SCCWRP and its collaborators can turn next to analyzing how each of the 10 variables affects in-stream biology.

» **Facilitating implementation of hydromodfication assessment tools:** A suite of SCCWRP-developed tools designed to assess a stream's susceptibility to hydromodification effects such as channel erosion has been transitioned into use in a variety of monitoring and regulatory programs across Southern California, providing effective new technologies for environmental managers studying how ecosystems can be altered by changing water-flow patterns. The tools, which include both field-screening tools and digital mapping software, have been incorporated into several municipal permit programs, the Stormwater Monitoring Coalition's Regional Watershed Monitoring Program, and a San Diego County initiative that aims to develop water-quality offsets for regional BMPs. The hydromodification tools were developed in cooperation with partners including the Redlands, Calif.-based geography technology company Esri, which helped SCCWRP produce automated procedures for running a landscape-scale tool for identifying sources of deposited sediment. SCCWRP also organized training with local municipalities and their contractors, and advised local programs on implementation.

» **Participating in an international case study in watershed management:** In an effort to understand how to more effectively manage urban watersheds,

SCCWRP and a team of international scientists have partnered to develop a series of recommended changes that environmental managers can make to reduce net pollution in watersheds in the Australian state of Victoria. The case study could have important implications for Southern California, which mirrors Victoria in that both have undergone rapid land-use changes and population growth. In a modeling report that was submitted to the Victoria-based utility company Western Waters in 2014, partnership scientists called for implementing a series of best management practices (BMPs) to improve watershed health in Victoria. The international partnership, known as the UC Irvine Water Partnerships for International Research (UCI Water PIRE), brought SCCWRP together with the Australian utility company and the University of California, Irvine. All of the agencies have benefitted from the ongoing coordination and cooperation, including during U.S.-based conferences such as the California Stormwater Quality Association and American Geophysical Union, and at undergraduate and professional workshops in Southern California and Melbourne, Australia. Meanwhile, at an international workshop planned for March 2015 in New Delhi, India, leading scientists from California, Australia and India will come together to evaluate BMP design as they work to more effectively manage highly urbanized watersheds in semi-arid climates and improve the health of aquatic ecosystems.

Pre- and post-fire pollutant loads in an urban fringe watershed in Southern California

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Abstract

Post-fire runoff has the potential to be a large source of contaminants to downstream areas. However, the magnitude of this effect in urban fringe watersheds adjacent to large sources of airborne contaminants is not well documented. The current study investigates the impacts of wildfire on stormwater contaminant loading from the upper Arroyo Seco watershed, burned in 2009. This watershed is adjacent to the Greater Los Angeles, CA, USA area and has not burned in over 60 years. Consequently, it acts as a sink for regional urban pollutants and presents an opportunity to study the impacts of wildfire. Pre- and post-fire storm samples were collected and analyzed for basiccations, trace metals, and total suspended solids. The loss of vegetation and changes in soil properties from the fire greatly increased the magnitude of storm runoff, resulting in sediment-laden floods carrying high concentrations of particulate-bound constituents. Post-fire concentrations and loads were up to three orders of magnitude greater than pre-fire values for many trace metals, including lead and cadmium. A shift was also observed in the timing of chemical delivery, where maximum suspended sediment, trace metal, and cation concentrations coincided with, rather than preceded, peak discharge in the post-fire runoff, amplifying the fire's impacts on mass loading. The results emphasize the importance of sediment delivery as a primary mechanism for post-fire contaminant transport and suggest that traditional management practices that focus on treating only the early portion of storm runoff may be less effective following wildfire. We also advocate that watersheds impacted by regional urban pollutants have the potential to pose significant risk for downstream communities and ecosystems after fire.

Citation

Burke, MP, TS Hogue, A Kinoshita, J Barco, C Wessel, ED Stein. 2013. Pre- and post-fire pollutant loads in an urban fringe watershed in Southern California. *Environmental Monitoring and Assessment* 185:10131–10145.

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Full text available by request: pubrequest@sccwrp.org

Metals and bacteria partitioning to various size particles in Ballona Creek storm water runoff

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Abstract

Many storm water best management practice (BMP) devices function primarily by capturing particulate matter to take advantage of the well-documented association between storm water particles and pollutants. The hydrodynamic separation or settling methods used by most BMP devices are most effective at capturing medium to large particles; however, these may not be the most predominant particles associated with urban runoff. The present study examined particle size distribution in storm water runoff from an urban watershed in Southern California and investigated the pollutant–particle associations of metals (Cu, Pb, Ni, and Zn) and bacteria (*enterococci* and *Escherichia coli*). During small storm events (≤0.7 cm rain), the highest concentration of pollutants were associated with a <6-mm filter fraction, which accounted for 70% of the per storm

contaminant mass but made up more than 20% of the total particle mass. The pollutant–particle association changed with storm size. Most pollutant mass was associated with >35mm size particles during a 5-cm rain event. These results suggest that much of the contaminant load in storm water runoff will not be captured by the most commonly used BMP devices, because most of these devices (e.g., hydrodynamic separators) are unable to capture particles smaller than 75mm.

CITATION

Brown, JS, ED Stein, D Ackerman, JH Dorsey, J Lyon, PM Carters. 2013. Metals and bacteria partitioning to various size particles in Ballona Creek storm water runoff. *Environmental Toxicology and Chemistry* 32:320-328.

SCCWRP Journal Article #0749
Full text available by request: pubrequest@sccwrp.org

WETLANDS

SCCWRP Accomplishments

Prior to passage of the federal Clean Water Act in 1971, government policies considered wetlands to be "wastelands" and subsidized their conversion to agricultural or urban land uses. Contemporary federal and state policies have recognized that wetlands are one of the most diverse and ubiquitous habitats in California, and today there are a host of state and federal programs and regulations aimed at protecting and restoring them. Defined as the transitional area between aquatic and terrestrial habitats, wetlands are integrated into most landscape settings and occur in a wide range of sizes and types, from small freshwater systems to larger brackish areas along the coast. Their unique position between wet and dry areas allows them to support distinctive plant and animal communities that provide a broad set of ecological functions and services for society, including habitat for sensitive species, flood attenuation, groundwater recharge, coastal protection, and recreational and aesthetic opportunities. However, wetland management and protection are challenging goals for California because the state lacks comprehensive programs for mapping and assessing wetland extent and condition. SCCWRP is working with partners across the state to develop tools and approaches for mapping wetlands that rely on advanced technologies and statistical approaches to assess their condition and value to society. SCCWRP also is working to identify and study wetland areas that could be altered by sea-level rise.

SCCWRP's wetlands research is organized around addressing three broad issues important to management and protection of wetlands: (1) Assessment, which is the area of wetlands research that revolves around establishing goals or targets for regulatory and management programs; it also includes improving understanding of the historical and contemporary extent and condition of wetlands. For this area, SCCWRP is working alongside the California Wetland Monitoring Workgroup − the state agency charged with coordinating wetland monitoring and assessment − to develop an integrated set of tools and approaches that can be used across agency programs to inform decisions about wetland management and make wetland information broadly accessible to agencies and the public. (2) Impacts, which is the area of wetlands research that focuses on understanding how both short- and long-term changes can potentially impact wetlands; it includes gaining understanding of short-term impacts from factors such as land-use changes, hydrologic modification, and contaminant input to wetlands, as well as long-term effects associated with climate change. (3) Uses, which is the area of wetlands research that is focused on understanding how wetlands can provide a broad suite of functions, services and beneficial uses to society, and how various actions by the environmental-management community affect this capacity.

Over the past year, SCCWRP had made significant strides in documenting historical wetland losses, developing a mapping program that uses probability to estimate the extent and distribution of contemporary wetlands, and assessing wetland areas characterized by a topographical depression, known as depressional wetlands, which historically have gone largely unmonitored. Accomplishments in 2014 include:

» **Tracking historical losses to Southern California's wetlands:** A study examining changes and losses to Southern California's wetland areas since the mid-19th century has concluded that 48% of the region's coastal estuarine habitats have disappeared. The study, which required overlaying 40 high-resolution historical topographical maps (T-sheets) of Southern California's shoreline with present-day maps, found that Southern California once had more than 330 individual coastal systems that provided more than 25,000 hectares of estuarine habitat. The hardest-hit area over the past 150 years or so has been Santa Barbara County, where 62% of total estuarine habitats have disappeared. The study, published in 2014, also found that vegetated marsh and salt and mud flats have been disproportionately affected, experiencing losses of 75% to 78%. Still, the overall 48% wetlands loss estimated by the study is significantly lower than previous estimates indicating a loss of more than 90% of California's wetlands. The study concluded that this difference could be explained by the precision of the latest analysis, differences in the types and locations of wetlands included in the study area, and disproportionate impacts to certain types of wetland areas. Going forward, this study can be used to help prioritize and guide decision-making about future wetland restoration projects.

» **Developing a cost-effective approach to track wetland extent and distribution:** SCCWRP and its partners have developed a standardized, cost-effective approach that environmental managers in California can adopt to comprehensively and reliably map wetland areas and track changes to them. The standard operating procedures and quality-assurance measures developed for this program are designed around a probability-based system that includes guidance on the optimum number and allocation of plots, plot size, and stratification. The goal of the program is to provide environmental managers with consistent, reliable high-quality data − an area that historically has been a source of struggle. The program also is designed to address challenges that environmental managers have faced in evaluating whether land-use changes are achieving state and federal "no net loss" goals

for wetlands. The California Water Quality Monitoring Council, which published the mapping protocols in 2014, is encouraging all wetland-monitoring programs statewide to use them. SCCWRP also completed mapping an initial 110 plots for a pilot project that demonstrates how the full program can be implemented. A draft scope of work for full program implementation has been developed that can be executed as soon as funding becomes available.

» **Assessing the condition of depressional wetlands:** A SCCWRP-led study of the condition of Southern California's depressional wetlands has found that more than half of these ecologically important areas are considered to be impacted by human activity. The study, which marked the first-ever systematic condition assessment of Southern California's depressional wetlands, found that only 21% to 43% are considered to be in minimally disturbed "reference" condition, depending on the indicator method used to assess condition. Depressional wetlands, which include vernal pools, freshwater marshes and wet meadows, are areas characterized by low topography where water tends to pool. Making up about 45% of California's 3.6 million acres of wetlands, depressional wetlands are especially important because they contribute to groundwater recharge and attenuation of surface runoff, thus reducing the impact of excessive flow to downstream watersheds and coastal ecosystems. The standardized procedure that SCCWRP developed to assess depressional wetlands relies on three indicators: benthic invertebrates, diatoms and the California Rapid Assessment Method (CRAM); collectively, these indicators paint a comprehensive picture of condition. The assessment methodology for this study was published in 2014; the full study report is due out in 2015.

Evaluating alternative temporal survey designs for monitoring wetland area and detecting changes over time in California

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ABSTRACT

Evaluation of wetland extent and changes in extent is a foundation of many wetland monitoring and assessment programs. Probabilistic sampling and mapping provides a cost-effective alternative to comprehensive mapping for large geographic areas. One unresolved challenge for probabilistic or design-based approaches is how best to monitor both status (e.g., extent at a single point in time) and trends (e.g., changes in extent over time) within a single monitoring program. Existing wetland status and trends (S&T) monitoring programs employ fixed sampling locations; however, theoretical evaluation and limited implementation in other landscape monitoring areas suggest that alternative designs could increase statistical efficiency and overall accuracy. In particular, designs that employ both fixed and nonfixed sampling locations (alternately termed permanent and temporary samples), termed sampling with partial replacement (SPR), are considered to efficiently and effectively balance monitoring current status with detection of trends. This study utilized simulated sampling to assess the performance of fixed sampling locations, SPR, and strictly nonfixed designs for monitoring wetland S&T over time. Modeled changes in wetland density over time were used as inputs for sampling simulations. In contrast to previous evaluations of SPR, the results of this study support the use of a fixed sampling design and show that SPR may underestimate both S&T.

CITATION

Lackey, LG, ED Stein. 2014. Evaluating alternative temporal survey designs for monitoring wetland area and detecting changes over time in California. *Journal of the American Water Resources Association* 1-12. DOI: 10.1111/jawr.12254.

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Selecting the optimum plot size for a California design-based stream and wetland mapping program

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ABSTRACT

Accurate estimates of the extent and distribution of wetlands and streams are the foundation of wetland monitoring, management, restoration, and regulatory programs. Traditionally, these estimates have relied on comprehensive mapping. However, this approach is prohibitively resource-intensive over large areas, making it both impractical and statistically unreliable. Probabilistic (design-based) approaches to evaluating status and trends provide a more cost-effective alternative because, compared with comprehensive mapping, overall extent is inferred from mapping a statistically representative, randomly selected subset of the target area. In this type of design, the size of sample plots has a significant impact on program costs and on statistical precision and accuracy; however, no consensus exists on the appropriate plot size for remote monitoring of stream and wetland extent. This study utilized simulated sampling to assess the performance of four plot sizes (1, 4, 9, and 16 km^2) for three geographic regions of California. Simulation results showed smaller plot sizes (1 and 4 km^2)

were most efficient for achieving desired levels of statistical accuracy and precision. However, larger plot sizes were more likely to contain rare and spatially limited wetland subtypes. Balancing these considerations led to selection of 4 km^2 for the California status and trends program.

Citation

Lackey, LG, ED Stein. 2014. Selecting the optimum plot size for a California design-based stream and wetland mapping program. *Environmental Monitoring and Assessment* 186:2599-2608.

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The salinity transition zone between the southern Everglades and Florida Bay: System functioning and implications for coastal zone management

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Abstract

Like many ecosystems around the world, the Florida Everglades is threatened by global change. One of the world's largest wetlands, it was described at one time as a vast, free-flowing "river of grass" extending from the Kissimmee chain of lakes to the Gulf of Mexico and Florida Bay (Douglas 1988). These subtropical wetlands support a rich diversity of plants, fish, and animals, including prolific populations of alligators, deer, panthers, manatees, wading and migratory birds, and mosquitoes. The historical Everglades encompassed a broad area of "ridge and slough" landscape (freshwater sloughs with periphyton mats, sawgrass ridges, and tree islands), marl forming prairies on adjacent higher ground, and to the south, mangrove forests and saline tidal flats of Florida Bay. Additionally, the very health and nature of the Everglades is closely tied to the volume, periodicity, and distribution of water entering the wetlands from Lake Okeechobee overflow. Over the past 100 years, however, the hydrology, chemistry, and biology of this ecosystem were altered dramatically to accommodate rapidly growing urban populations and industrial agriculture in south Florida. Two major effects on the ecosystem include large scale diversions of fresh water from the Everglades to the Atlantic Ocean and Gulf of Mexico and the conversion of large areas of wetlands for agricultural and urban uses. Now this dynamic relationship between the upstream freshwater lake system and the downstream "river of grass" is fundamentally altered by encroaching anthropogenic pressures.

Citation

Day, J, F Sklar, J Cable, D Childers, C Coronado-Molina, S Davis, S Kelly, C Madden, B Perez, E Reyez, D Rudnick, M Sutula. 2013. The salinity transition zone between the southern Everglades and Florida Bay: System functioning and implications for coastal zone management. Texas A&M University Press. pp. 1-24 in: *Gulf of Mexico Origin, Waters, and Biota*. J Day and A Yanez-Arancibia (eds).

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Using regional stormwater monitoring programs to provide reference data for wetland mitigation performance evaluation

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Abstract

Reasonable, defensible, and enforceable performance standards are a linchpin for improving the success of wetland compensatory mitigation. Well-crafted performance standards establish agreed-upon targets that can be used to objectively evaluate progress and, ultimately, success at compensating for permitted wetland losses. Targets should be crafted to guarantee that desired wetland functions are recovered yet be practical given the constraints and uncertainty inherent in reestablishing natural systems. This balance can be particularly challenging in urban or agricultural settings where ecological processes may be altered by past or present land use practices. For example performance standards should account for changes in hydrology and sediment yield, introduction of invasive species, limitations on propagule recruitment, and/or general encroachment and increased edge effects that may affect the ultimate function of mitigation sites.

Citation

Stein, ED. 2013. Using regional stormwater monitoring programs to provide reference data for wetland mitigation performance evaluation. *National Wetlands Newsletter* 35:13-14.

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California Aquatic Resources Status and Trends Program: Mapping methodology

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Abstract

The ability to track changes in wetland area is a foundational element of California's wetland monitoring and assessment programs. It not only provides the basic information to report on wetland status and trends over time, but is also crucial

for accurately assessing the Federal and State "no net loss" policies in terms of wetland quantity and evaluating the effectiveness of current regulatory and management programs (e.g., Porter-Cologne Water Quality Control Act, Clean Water Act §401, CA Fish and Wildlife Code §1600). Furthermore, monitoring trends and tracking net change provide a foundation for monitoring the long-term effects of climate change and other natural disturbances (e.g., fires, floods, and droughts) on wetland resources, and the effect of these trends on habitat and species conservation efforts.

Developing an agreed upon approach for assessing wetland gains and losses using a combination of ambient surveys and project tracking is a necessary first step to better our capacity to answer fundamental management questions. Complete survey mapping of a state the size of California on a regular basis is cost prohibitive and logistically challenging. A cost estimate to update mapping of streams and other aquatic resources is $3,000 per USGS quadrangle, and California has 2,800 quadrangles. Not only does the state of California lack the $8.5 million for comprehensively mapping, but this cost would need to be incurred every 5 to 10 years in order to assess change over time. The National Wetland Status and Trends (S&T) Program (administered by U.S. Fish and Wildlife Service) has addressed this challenge by adopting a probabilistic approach to wetland change assessment. Probabilistic mapping provides a method to produce extent and trend information in a practical, cost-effective manner. Because probability-based mapping requires significantly fewer resources, it allows for more frequent production of maps and extent and trend estimates. These probabilistically-selected maps will serve as updates to the California Aquatic Resources Inventory (CARI), a standardized statewide map of wetlands, streams, and riparian areas that is used for Level-1 landscape assessment. The maps can also serve as a sample frame to support Level-2 or -3 condition assessments if locations for condition assessment are selected from the status and trends plots.

Although sufficient for a national assessment, the National S&T plots by themselves are insufficient for assessing status and trends of California's wetland and riparian resources. The U.S. Fish and Wildlife Service National S&T Program includes only 257 plots in California, covering approximately 0.6% of the land area, mostly concentrated along the coast. Furthermore the national program does not include streams, and is based on older vintage National Wetlands Inventory maps that omit many of the wetland and riparian areas of California.

Previous U.S. Environmental Protection Agency (USEPA) funding supported development of the first phase of a status and trends program for California. That effort evaluated other Federal and State programs, identified key technical challenges for S&T implementation in California, and used a model-based approach to test various design alternatives. The Phase 1 effort produced a set of recommendations for optimum plot allocation, plot size, and stratification, and tested the design in a limited geographic area. These analysis conducted during Phase 1 of this project resulted in a recommendation that S&T plots be 4 km^2 in size (2 km x 2 km) and that mapping for each plot include all elements within sample plots, including aquatic resources and upland land use. This will provide information about proximal anthropogenic influences and impacts on wetlands and aquatic resources and allow other programs to take advantage of the plots to fulfill part of their programmatic needs.

Although all natural and anthropogenic resources within each plot will be mapped, the main focus and intensity will be devoted to the aquatic resources. Unlike other programs, the California S&T program includes wetlands and streams (regardless of whether or not the streams include wetland areas). Standard procedures and quality assurance measures will help minimize mapping and interpretation errors, which in turn will maximize the confidence and reliability of the mapping results.

The purpose of this document is to describe the mapping standards and methods that should be applied when mapping wetlands and other aquatic resources (e.g., lakes, streams) within the California Status and Trends (S&T) plots. This document provides only minimal guidance pertaining to the upland and developed portions of the S&T plots, as they relate to interpreting changes in aquatic resources. Additional protocols would need to be developed, consulted and/or applied for programs that need detailed information about upland resources.

CITATION

Stein, ED, J Brown, K Cayce, M Klatt, M Salomon, P Pendleton, S Dark, K O'Connor, C Endris. 2014. California Aquatic Resources Status and Trends Program: Mapping methodology. Technical Report 833. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0833
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Northern San Diego County lagoons: Historical ecology investigation

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ABSTRACT

Driving between Oceanside and San Diego on Interstate 5, one can't help but notice the scenic expanses of water and marsh crossed by the freeway. These six estuaries – Buena Vista, Agua Hedionda, Batiquitos, San Elijo, San Dieguito, and Los Peñasquitos lagoons, each occupying a valley cut into the marine terraces of San Diego County – are an extremely important coastal wetland resource for the Southern California region. They are valuable ecosystems both for native wildlife and for the people who live and recreate in and around their edges. Compared to the extensive loss of coastal wetlands in neighboring areas, northern San Diego County ("North County") estuaries have remained remarkably

protected over the past decades. This study finds that North County lagoons have lost only about 15% of their former estuarine area since the 19th century, a significant but relatively modest decline in the context of estimated regional losses of about half of total estuarine area across Southern California coastal systems.

At the same time, however, North County lagoons have experienced profound and widespread transformations as a result of impacts from a variety of land uses. Habitat loss and conversion have in many cases dramatically altered the ecosystem and social services provided by these estuaries. In addition, lagoon ecosystems have been degraded by an array of activities, including dredging and filling, the construction of transportation infrastructure, discharge of sewage effluent and other pollutants, dam construction and groundwater pumping, and urbanization. These and other anthropogenic modifications have heavily impacted the lagoons' character, including ecological patterns, water quality, tidal exchange, and freshwater inputs.

Today, these estuaries are the focus of numerous restoration and management efforts that aim to enhance lagoon function by reducing flooding, increasing tidal circulation, and increasing the acreage and quality of wildlife habitat, among many other objectives. As the region's scientists and managers take advantage of the significant opportunities presented by these systems, they face challenging decisions about what the goals of restoration should be. The study of the past can help inform these decisions by providing valuable knowledge about system characteristics under more natural conditions, as well as an understanding of how these characteristics have changed over time in response to human alterations to the landscape. Understanding the interaction between the ecological mosaic and underlying topographic, climatic, and hydrologic gradients, how these habitats supported native species, and how elements of the landscape have persisted or changed is key to designing and managing locally appropriate future systems that are flexible, adaptive, and resilient to dynamic environmental conditions.

Though the study of these systems' past characteristics is a key component of determining appropriate restoration objectives, to date there has been no consensus about the natural structure and function of northern San Diego County lagoons as they existed in the recent past. While previous studies have addressed some aspects of the region's paleoecology and historical ecology, there has been no integrative and spatially explicit assessment of regional historical ecological and hydrogeomorphic patterns and processes. Further, the natural hydrology and ecology of estuaries in small southern California watersheds in general has not been well studied.

Citation

Beller, E, S Baumgarten, R Grossinger, T Longcore, ED Stein, S Dark, S Dusterhoff. 2014. Northern San Diego County lagoons: Historical ecology investigation. Technical Report 831. Southern California Coastal Water Research Project. Costa Mesa, CA

SCCWRP Technical Report #0831
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Wetlands of the Southern California coast: Historical extent and change over time

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Abstract

Southern California's coastal wetlands are an interrelated set of resources that collectively provide a broad suite of ecological, hydrological, and biogeochemical functions. Managing and restoring these systems requires a regional perspective that can inform holistic decision making. Knowledge of historical conditions provides a baseline of the extent and condition of wetlands lost, and is important to guide regional planning. The U.S. Coast and Geodetic Survey topographic sheets (T-sheets) provide the most important single source for understanding the physical and ecological characteristics of the US shoreline prior to Euro-American modification. Their depictions of coastal wetlands and other estuarine habitat types can provide relatively consistent information about the extent and distribution of those systems along the southern California Bight (SCB) prior to substantial human alteration. Although most appropriately used in conjunction with other data sources, the T-sheets can provide a foundation for regional analysis and a platform on which future, more detailed investigations can be based.

This project builds on earlier efforts to provide comprehensive analysis of the 40 T-sheets that cover the SCB from Point Conception to the U.S.-Mexico border. High quality scans of the original T-sheets produced between 1851 and 1889 were obtained along with the surveyor notes. T-sheets were digitized, georeferenced, and interpreted in order to provide a map of coastal estuaries (both large and small) and coastal drainage systems representing conditions along the SCB coast in the mid-late 19th century. This analysis was used to answer the following questions:

1) How much total estuarine habitat was there historically (i.e., as mapped on the T-sheets) compared to today?

2) How many total coastal systems occurred historically?

3) What has happened to historical estuarine habitat types?

Extent of coastal estuarine habitats

The SCB coast supported approximately 19,591 hectares of estuarine habitats. Approximately 40% of this area was vegetated wetlands (e.g., salt marsh), 25% was unvegetated wetlands (e.g. salt flat and mudflat), and the remaining 35% was subtidal water. In addition to these habitat types, an additional 5,496 hectares of "other wetlands" were mapped on the T-sheets. These included dune and beach, woody vegetated wetlands, high marsh habitat, isolated ponds, and riverine habitat.

Over half (~57% or ~11,000 hectares) of all historical estuarine habitats were found in San Diego County, mostly associated with Mission and San Diego Bays. Both Los Angeles and Orange Counties contained about 15% each of the total historical estuarine area. The largest expanses of historical salt flats occurred in Los Angeles County.

Number of estuarine systems

A total of 331 coastal systems occurred along the SCB coast. Approximately two-thirds of these systems consisted of small coastal drainages without any associated terminal wetlands. Individual coastal systems were relatively evenly distributed along the coast, with each county having between 60 and 90 systems. The distribution of systems by size was also relatively uniform across the counties. The exceptions were a slightly higher concentration of medium and large systems in San Diego County and slightly more channel only systems in Los Angeles County. On a regional scale, larger systems occur in three areas distributed along the SCB coastline, south San Diego, Long Beach, and southern Ventura County. These three nodes were connected through strings of medium and smaller wetlands.

The 331 systems can be grouped in 15 distinct archetypes (or distinct compositions) representing combinations of size and dominant habitats. These archetypes tended to be spatially aggregated along the coast into loose "families" of systems.

Change over time

Since ca. 1850 there has been an overall loss of 9,317 hectares, or 48% of historical estuarine habitat types along the SCB coast. Estuarine vegetated wetlands have experienced the greatest loss in terms of absolute area (-5819 ha, 75% loss), while estuarine unvegetated wetlands have experienced the greatest proportional loss of 78% of historical extent. In contrast, the contemporary landscape represents a 5% increase in subtidal habitat from historical extent. These differential losses have shifted the proportional composition of Southern California estuaries. Historically there was a relatively even split between estuarine vegetated (40%), estuarine unvegetated (25%), and subtidal water (35%). Currently the proportional composition is heavily weighted towards subtidal water (71%) while estuarine vegetated (19%) and unvegetated (10%) make up less than one-third of the total area combined.

Declines in estuarine area vary by county. Total losses across all counties range from 62% in Santa Barbara to 31% in San Diego. Additionally, the composition of estuaries in the counties has shifted. In the southern most counties (Los Angeles, Orange, and San Diego) there has been a significant increase in subtidal water while both intertidal and vegetated wetlands have decreased. Santa Barbara and Ventura Counties have maintained an estuarine composition similar to that seen in ca. 1850.

Our estimated estuarine habitat losses, although substantial, are significantly lower than previously reported estimates of over 90% total wetland loss in California. Overall estuarine habitat area changes reflect and, to some extent, hide the disproportionate impacts to different estuarine habitat types. For example subtidal habitat has increased slightly while other types have decreased dramatically. Differences from other estimates may also be explained by the fact that our analysis is more precise than that used to produce previous estimates and/or that previous estimates may have included other wetland types or locations not included in this study. Lower than "expected" rates of loss may also reflect policies and programs over the last 40 years aimed at protecting and restoring coastal wetlands. Looking to the future, knowledge of historical wetland extent and patterns of loss can be used to inform future planning for diverse and resilient coastal landscapes.

This report provides a synthesis of the main results of our analysis. Scanned images of the T-sheets, GIS and Google Earth layers of the maps, and the underlying data from this project are available at www.caltsheets.org.

CITATION

Stein, ED, K Cayce, M Salomon, DL Bram, D De Mello, R Grossinger, S Dark. 2014. Wetlands of the Southern California coast: Historical extent and change over time. Technical Report 826. Southern California Coastal Water Research Project. Costa Mesa, CA.

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Regional Monitoring

SCCWRP Accomplishments

Southern California environmental managers spend an estimated $50 million every year on monitoring aquatic environments, but have struggled to answer the big-picture questions being asked by the public: "Is it safe to swim in the ocean?" "Are locally caught fish safe to eat?" and "Are local ecosystems adequately protected?" The reason? Most of this money is allocated to keep tabs on the relatively compact areas that surround sewage treatment plants and storm drain outfalls − monitoring that is required under state and federal laws. Consequently, when scientists compile this compliance-based monitoring data from dozens of agencies, the resulting regional picture is skewed. Recognizing this challenge, SCCWRP has stepped in to coordinate and facilitate wide-scale regional monitoring programs across a variety of habitats, including steams, wetlands, estuaries, beaches and coastal waters. For each monitoring program, SCCWRP works with up to 100 local and regional agencies to standardize data collection and coordinate analysis efforts, leveraging the limited resources of many to obtain comprehensive data on some of the region's most pressing environmental challenges. These programs are among the top regional monitoring programs in the nation and have served as models for developing programs internationally.

SCCWRP's best-known monitoring program is the ongoing Southern California Bight Regional Monitoring Program, conducted every five years since the mid-1990s. The program mobilizes participating agencies to collect data from across a much greater expanse than just their outfall zones, allowing environmental managers to paint a comprehensive picture of the health of coastal waters that stretch from Point Conception in Santa Barbara County to just south of the U.S.-Mexico border. The Bight program's freshwater counterpart, the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program, was launched in 2008 to monitor an area that stretches from the Ventura River in Ventura County to the Tijuana River near the U.S.-Mexico border. The key to success in developing integrated monitoring designs is SCCWRP's ability to bring all parties to the table − from local and regional agencies to state and national entities − to work toward agreement on goals, study design and data interpretation. Not only do the comprehensive data sets help environmental managers establish appropriate priorities and goals for addressing big-picture challenges, but regional monitoring also fosters productive interactions among dischargers and regulators as they develop and collaboratively interpret monitoring information and implement findings. Regional monitoring also provides an important launching platform for SCCWRP's member agencies and research collaborators to test new technologies and assessment tools.

Over the past year, SCCWRP has facilitated gathering and analyzing data for habitats that haven't been previously studied or that haven't been as extensively studied. From this data, SCCWRP has begun to answer important questions about how human activity has impacted these habitats, allowing environmental managers to make informed decisions about how best to allocate resources and funding. Accomplishments in 2014 include:

» **Studying impacts of stormwater runoff on Southern California's marine protected areas:** A comprehensive monitoring survey of water quality in Southern California's marine protected areas following rainfall has found that urban runoff appears to be having only a minor impact on these ecologically sensitive areas. During the study, which was published in 2014, researchers compared water quality in the region's 14 Areas of Biological Significance (ASBS) following rainfall to water quality in locations far removed from urban influences. Although researchers identified individual, isolated sites where contamination might pose a threat to marine ecosystems, overall pollutant levels in ASBS zones mirrored undeveloped areas that are unaffected by human activity. In addition to demonstrating that rain runoff was generally not toxic to three species typically found in ASBS (sea urchin, California mussel, and giant kelp), researchers also surveyed 24 rocky intertidal sites, which are known to be among the habitats most directly impacted by flowing storm drains at the shoreline. The study showed that the ASBS rocky intertidal communities were largely healthy. While the drains that discharge directly into ASBS zones don't appear to be responsible for causing direct toxicity, SCCWRP and the Southern California Ocean Observing System demonstrated in a follow-up study that stormwater plumes from nearby rivers and streams can drift into ASBS zones, posing an exposure risk in areas like Malibu and Newport Beach. The streams and rivers responsible for these potentially toxic plumes aren't directly subject to strict ASBS water-quality regulations, creating an ongoing concern for environmental managers.

» **Developing a reliable way to track health of rocky reefs:** In ongoing efforts to protect Southern California's 121,000+ acres of rocky subtidal reefs, environmental managers have struggled to gauge the overall health of these unique habitats that sustain a huge array of biodiversity, including the region's famous kelp forests − and if and to what extent urbanization is impacting these sensitive ecosystems. The challenge is that human-triggered effects are difficult to differentiate from natural variation in kelp bed dynamics, which tend to

fluctuate wildly. And that's where SCCWRP has stepped in with a promising solution. Over the past year, SCCWRP has worked with the Marine Protected Area Monitoring Enterprise to design a quantitative index of biological health for rock reef subtidal communities. The index predicts which fish, invertebrates and algae should be present at a site that is not impacted by humans; it's based on a series of physical factors known to account for natural variation like water temperature and type of rocky bottom, among others. Then, researchers can compare the index's predictions to which organisms are actually present at the site. To date, SCCWRP has applied this tool to nearly 300 surveys of rocky reefs collected during regional monitoring. The index results indicate that less than 20% of Southern California's 140 rocky reefs are substantially impacted, and that fishing tends to have a more significant impact on the reefs' health than degraded water quality. A preliminary version of this new index assessment tool is expected to be released in 2015.

» **Comprehensively assessing condition of Southern California's streams:** A five-year monitoring study of Southern California's perennial wadeable streams has found that only 13% of the region's 4,300 miles of streams are considered biologically intact, according to three key indicators of condition. The comprehensive study by the Southern California Stormwater Monitoring Coalition evaluated stream condition by measuring the health of benthic infauna, algae and riparian habitat; 87% of stream miles were considered biologically degraded under one or more of these indicators. The study, which also examined stressors that may be contributing to degraded condition, found that nutrients, sulfate, and habitat degradation are the most prevalent, high-risk stressors that impact Southern California's streams. Meanwhile, three other stressors studied – metals, pyrethroids and toxicity – were found to be either spatially limited or weakly associated with degraded biological condition. These findings are significant because metals, pyrethroids and toxicity tend to get proportionately more attention from environmental managers than nutrients, sulfate and habitat degradation; hence, this study will help managers reassess their priorities. SCCWRP served as the program's technical lead; the final report will be published in 2015.

Southern California Stormwater Monitoring Coalition 2014 Research Agenda

Kenneth Schiff[1], Eric D. Stein[1], Sara Aminzadeh[2], Alexandria Boehm[3], Gary Hildebrand[4], Larry Honeybourne[5], Iraj Nasseri[6], Peter Ode[7], Scott Taylor[8], David Senn[9], James Smith[10], Chris Sommers[11], Eric Strecker[12]

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[10]*San Diego Regional Water Quality Control Board, San Diego, CA*
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ABSTRACT

Collaboration is a powerful vehicle towards common understanding. The Southern California Stormwater Monitoring Coalition (SMC) exemplifies this collaborative synergy, having spent the last 10 years filling foundational gaps in knowledge about how to improve stormwater management. Creating monitoring infrastructure, deciphering stormwater mechanisms and processes, and assessing receiving water impacts have brought tremendous leaps in how dischargers and regulators address the challenging issues of urban runoff. Cumulatively, the SMC and its project partners has expended over $6M to fill these data gaps.

The SMC has improved stormwater management as they have learned by implementing applied research projects. The SMC addressed peak flow hydromodification, and the result was interim peak flow criteria and the development of monitoring and management tools for identifying and minimizing hydromodification impacts in at-risk stream segments. The SMC addressed stream biological assessments, and the result was an integrated, coordinated regionalized monitoring program that provides holistic views of ecosystem health and has become the foundation of California's upcoming biological integrity program. The SMC addressed low impact development (LID), and the result was a practitioners' manual on the most efficient designs for LID management practices. These are just a few examples of the meaningful impact from collaborative SMC projects. Virtually every project the SMC has undertaken has led to some change in stormwater management and/or policy.

Despite the success of the SMC, numerous stormwater issues persist and unresolved problems stymie regulatory and regulated agencies. After a decade of steadily improving progress, the remaining challenges are much more difficult to resolve. For example, the SMC can now identify where stream biological communities are impacted, but deciphering the cause(s) of the impact remain elusive. The SMC installs numerous structural control measures such as on-site retention basins, but optimal sizing, location, and flow controls have yet to be defined for the various precipitation and geologic conditions found throughout Southern California. The SMC now has quantifiable accuracy and precision limits for measuring routine, traditional pollutants identified in regulatory permits, but have little idea about the occurrence or toxicity for thousands of non-traditional chemicals of emerging concern that may be impacting their stream.

The SMC is about to recommit to their interagency collaboration. A master agreement, the document that binds them together as an entity, will be signed before fiscal year-end.

The master agreement calls for a Five-Year Research Agenda, a forward-looking list of issues to address as implementable projects. This document is that Research Agenda and it will serve as the road map for the SMC.

CITATION

Schiff, K, ED Stein, S Aminzadeh, A Boehm, G Hildebrand, L Honeybourne, I Nasseri, P Ode, S Taylor, D Senn, J Smith, C Sommers, E Strecker. 2014. Southern California Stormwater Monitoring Coalition 2014 Research Agenda. Technical Report 828. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0828
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/828_SMCResearchAgenda.pdf

Newport Bay Watershed Monitoring Evaluation

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ABSTRACT

The Newport Bay Watershed is a valuable ecological resource containing over 300 km of stream miles and the largest estuary in Southern California. Water bodies within the watershed are also a valuable human resource for fishing, swimming, and non-contact recreation. However, water bodies within the Newport Bay Watershed are also potentially at risk of pollution from urban runoff, boating activities, historical inputs, agricultural legacy inputs, and alterations in groundwater hydrology. As a result, a number of regulatory management programs have been instituted including NPDES discharge permits and TMDLs. Associated with these management programs are monitoring requirements to assess the magnitude of the water quality impact and track improvements as management actions are implemented. Some of these monitoring programs have existed for decades while others have just begun, but old and new monitoring requirements are rarely integrated with one another. As a result, there is concern about inefficiencies once management questions have been addressed.

The goal of this project was to evaluate the effectiveness and efficiency of monitoring programs in the Newport Bay Watershed, and then make recommendations for improvement. This evaluation followed a four step process to:

- Develop the list of management questions,
- Create an inventory of existing monitoring efforts,
- Assess the effectiveness of the current monitoring elements to address the questions of interest, and
- Redesign selected monitoring elements for improved effectiveness and efficiency to address the questions of interest.

This process was implemented using an Advisory Committee that included regulatory, regulated, advocacy, and academic stakeholders from throughout the watershed.

Five management questions were identified for which monitoring data would help make decisions. These five questions included:

- Is the ecosystem protected?
- Is it safe to eat the seafood?
- Is it safe to swim?
- Are we in attainment of water quality standards?
- What are the sources of pollutants?

Embedded within each question is also an element of trends. The inventory of monitoring effort indicated that there is a tremendous quantity of effort expended on monitoring in the Newport Bay Watershed, the likes of which is rarely seen in California. In total, 13 long-term monitoring programs were identified that sample 139 sites for 399 different constituents. The net result was over 32,000 sample analyses per year.

After a series of one-on-one interviews with many of the Stakeholder Advisory Committee members, the assessment of current monitoring effort fell into one of four categories:

- Monitoring that was effective and efficient
- Monitoring that was effective, but inefficient
- Monitoring where effectiveness and efficiency was uncertain
- Monitoring that does not currently exist

The most effective and efficient monitoring programs were the regional-based programs that incorporated the Newport Bay Watershed within the greater Southern California region. These regional programs, such as the Southern California Bight regional marine monitoring program that samples the bay or the Stormwater Monitoring Coalition regional stream monitoring program, effectively addressed the “ecosystem protection” question. Well-developed assessment tools and monitoring infrastructure, plus placing the Newport Bay Watershed within the context of other Southern California watersheds, provided scientifically sound answers at watershed scales.

A second effective monitoring program worthy of continued investment was the beach monitoring program conducted by the Orange County Health Care Agency for assessing the “safe to swim” question. This monitoring program is highly valued by the public and has documented water quality improvements as management actions have been implemented to clean beach water quality. Mass loading monitoring programs, whereby sampling stations are located at the end of major tributaries to Newport Bay to answer questions about “attainment of water quality standards” and “sources of pollutants,” was deemed effective, but not efficient. These mass loading sites are sampled weekly, sometimes for decades, and concentrations are compared to receiving water standards or TMDL load allocations. In many cases, the monitoring has shown a decrease in concentrations and loads that correspond to management actions ameliorating upstream pollutant sources. Re-answering the questions on such a frequent basis was no longer necessary.

Statistical power analysis, based on the results from 2002-2012, indicated that sampling could be reduced to quarterly in dry weather for individual mass loading stations. Selecting optimal sampling frequencies based on power analysis for answering trends questions is recommended, particularly should concentrations begin to increase. The power analysis also confirmed that an optimized sampling effort for trends will provide sufficient data to make statistically sound conclusions about attainment of regulatory thresholds.

The TMDL monitoring programs for selenium and pesticides have only recently been designed and few data have been collected to address their questions regarding "attainment of water quality standards." As a result, monitoring effectiveness and efficiency was uncertain. Therefore, revisiting the design of these monitoring programs after additional data has been collected is recommended.

There currently is no ongoing monitoring program for assessing the "safe to eat the seafood" question in Newport Bay. Angler warnings for seafood consumption exist along the open coast of Newport Beach, but there is insufficient data within the Bay to make conclusions about whether similar warnings are needed. Two individual monitoring projects have collected samples of seafood tissues from within the Bay, but these projects are not recent and the sparse results were mixed. However, the RWQCB has recently completed a tissue sampling program that included bioaccumulation through several trophic levels including sport fish. Waiting until these data are fully analyzed before making a decision about designing and implementing an ongoing seafood monitoring program is recommended.

CITATION

Schiff, KC, AE Fetscher, MM Hanken. 2014. Newport Bay Watershed Monitoring Evaluation. Technical Report 815. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0815
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/815_NewportWatershedMonitoring.pdf

Assessing Areas of Special Biological Significance exposure to stormwater plumes using a surface transport model

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ABSTRACT

Areas of Special Biological Significance (ASBS) are state water quality protected areas that, by legislative order, are not allowed to "receive discharges of waste" and must "maintain natural water quality." However, there are currently over 1,600 stormwater outfalls to ASBS statewide, the vast majority draining extremely small coastal catchments. The regulated parties have been rigorously working with the State Water Resources Control Board to ensure these outfalls do not contain waste. Meanwhile, much larger watersheds that discharge nearby ASBS, but not in them, are not subject to ASBS regulations. As a result, there is concern that plumes from these much larger watersheds may be transported into ASBS altering natural water quality. The goal of this study is to conduct preliminary modeling exercises to assess the potential of the plumes from large, neighboring watersheds to negatively impact ASBS water quality in Southern California.

Methods

The conceptual approach for this study was to estimate the probability of plume exposure in ASBS based on a transport model that uses High Frequency (HF) radar derived surface current data as input. The model used two years (January 1, 2008 - December 31, 2009) of surface current data for model runs and was applied to 20 rivers that discharge proximal to six ASBS from Malibu to San Diego. The plume probability exposure map was created by tracking 50 virtual water parcels released hourly, 1 km offshore of each river system. The cumulative number of tracers for a moving 3-day window (3600 tracers) were tracked for a given modeled time period. The probability of exposure was calculated for each ASBS by dividing the total number of virtual water parcel tracers advected into the ASBS by the total number of parcels introduced into the study region. A detailed description of the model assumptions, limitations and validation results is included in the full report.

Plume exposure probability

The ASBS with the greatest extent and largest magnitude of exposure probability is the Mugu Lagoon to Latigo Point ASBS. Nearly half of this ASBS has a probability of plume exposure between 10-20% from the discharge of Calleguas Creek. The Robert Badham and Irvine Coast ASBS had the second greatest extent and magnitude of exposure probability; 100% of these ASBS had a probability of exposure between 1-10% from the discharge through Newport Bay. The ASBS with the least extent and smallest magnitude of exposure probability is Heisler Park where there was virtually no (<1%) probability of plume exposure. However, the probability of exposure from the Laguna Canyon Channel could not be determined.

The next steps for the Mugu Lagoon to Latigo Point or Robert Badham ASBS is to conduct more detailed studies focused on empirically measured plume tracers and associated water quality. Examples of appropriate follow-up studies might include ship-based salinity and turbidity measurements, in conjunction with real-time HFR surface currents. These measurements can then be placed in context with similar measurements from the smaller, but more localized, regulated ASBS discharges.

CITATION

Rogowski, P, E Terrill, L Hazard, K Schiff. 2014. Assessing Areas of Special Biological Significance exposure to stormwater plumes using a surface transport model. Technical Report 817. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0817
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/817_ASBSPlumes.pdf

Areas of Special Biological Significance: Bioaccumulation monitoring

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Abstract

The California Water Resources Control Board (SWRCB) has designated Areas of Special Biological Significance (ASBSs) as marine regions that require water quality protection. Discharges of waste into ASBSs, such as polluted storm water, are prohibited, but the State Water Resources Control Board (SWRCB) grants exceptions if it can be shown that the protection of marine life in ocean waters is not compromised. The standard for protection is that discharges "shall not alter natural ocean water quality in an ASBS" (SWRCB Resolution 2012-0012). In California, there are approximately 1,658 known discharges into ASBSs, nearly all of them storm water outfalls, which have a potential to impact ASBS water quality.

Wet-weather water column contamination in ASBS receiving waters was monitored in 2008. In order to define "natural," the study used reference sites that were minimally impacted by human activities. The results from this survey found concentrations near discharges were, on average, similar to concentrations near reference sites. However, there were individual ASBS discharge sites that were greater than reference site based natural water quality thresholds. While these results were encouraging, the study did not focus on bioaccumulating compounds.

Driven by the needs of the SWRCB, the goal of this project was to answer the following questions forbioaccumulative contaminants. 1) What is the range of natural water quality for bioaccumulative compounds, as defined by mussel tissue sampled near reference stations? 2) Is the water quality for bioaccumulative compounds at ASBS discharge stations similar to that at reference stations representing natural water quality? Mussels are filter feeders that will accumulate contaminants over a longer period of time compared to storm water grab samples, and will bioconcentrate contaminants resulting in lower analytical method detection limits. Mussels have been used for decades in NOAA's Mussel Watch Program to monitor bioaccumulative contaminants across the U.S. coastline, but have not been previously utilized to assess ASBS water quality.

Citation

Dodder, N, W Lao, D Tsukada, D Diehl, K Schiff. 2014. Areas of Special Biological Significance: Bioaccumulation Monitoring. Technical Report 816. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0816

Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/816_ASBSBioaccumulation.pdf

Information Technology and Visualization

SCCWRP Accomplishments

Monitoring, assessment and management of aquatic ecosystems is a data-driven process, with millions of dollars spent every year in Southern California on the collection of water-quality monitoring data. To effectively use data, the approach that scientists take in acquiring, managing and assessing data must be well-documented. The goal is to generate data that are reproducible, consistent and comparable among the organizations that acquire, share and aggregate this information. Increasingly, environmental managers also are demanding sophisticated ways to visualize data, in ways that quickly and cohesively communicate big-picture ideas and complex findings; these visualization tools include data dashboards, map-based scenarios and virtual-reality simulations that can alter conditions or decisions to examine what-if scenarios. SCCWRP is at the forefront of efforts to develop and standardize data management across Southern California, beginning with an ocean-monitoring pilot study in 1994 that has evolved into the ongoing Southern California Bight Regional Monitoring Program. The development of standardized data collection and management protocols through the Bight program and others has greatly improved data quality and comparability throughout the region, offering environmental managers comprehensive, detailed snapshots of the condition of coastal waters in Southern California and beyond. Signature data-collection initiatives such as the Bight program also serve as national models for effective environmental-monitoring design.

As SCCWRP advances its research agenda to more efficiently and effectively leverage emerging information technologies in data acquisition and analysis, new and emerging technologies are evaluated through the lens of how they can improve the data workflow. This workflow falls into three main stages: (1) data acquisition, (2) data checks for quality, also known as Quality Assurance/Quality Control (QA/QC) management, and (3) analysis and output of results. To improve quality, consistency and speed of data collection, SCCWRP is pursuing a number of emerging technologies for field data acquisition. To allow environmental researchers and managers to evaluate potential outcomes based on various assumptions and hypothetical courses of action, SCCWRP is pursuing development of environmental index calculators, data dashboard and visualization products, and scenario tools. SCCWRP's goal is to provide environmental managers and the public with consistent and transparent analytical methods and outputs, so the science developed by SCCWRP and its collaborators can be effectively used to inform management action.

During the past year, SCCWRP has been pursuing development of both data acquisition and data output technologies. These efforts have given SCCWRP and its collaborators new tools to more reliably and consistently collect and analyze data. Accomplishments in 2014 include:

» **Developing a mobile app for submitting human health data:** SCCWRP has developed a custom mobile app to allow San Diego surfers enrolled in a four-month epidemiological study to report how often they entered the ocean and how they were feeling each day. The Surfer Health Study app, which can be used on both smartphones and tablets, has allowed SCCWRP and its collaborators to investigate if humans are getting sick from the urban runoff that flows down to the coastal ocean following Southern California rainstorms. Built for both the Android and Apple operating platforms, the app has provided for the collection of reliable, weekly health data from hundreds of study participants in 2014 and 2015. Following successful deployment during a 2014 pilot study, SCCWRP refined the app by improving the user's ability to edit or resume weekly data entry, by enhancing data quality and consistency through the study period, and by sending automated reminders via text message and email to study participants. The data system, meanwhile, was designed to capture and append beach condition and weather data from live web services and associate this information with each participant's surfing dates and locations.

» **Paving the way for mobile microscopy:** Working in collaboration with scientists at UC Berkeley, SCCWRP has adapted and begun testing a portable, handheld microscope that allows for high-quality imagery to be captured on an attached cell phone. The CellScope, originally designed by a UC Berkeley lab for use in remote medical clinics, has been modified for environmental field studies with the addition of elements such as a detachable enclosure that covers the microscope stage and allows for better lighting control when working outdoors. Once this updated version of the SCCWRP CellScope has been fully tested, SCCWRP can offer training for partners interested in implementing this technology as part of their own data-collection efforts.

» **Simplifying calculations of stream indices:** SCCWRP has developed a web-based tool that allows users to automatically perform the calculations necessary to assess the health of wadeable streams in Southern California. The algaeMetrics Calculator calculates three of the main benthic algal indices for Southern California's wadeable streams, providing a simple and consistent way for environmental managers to quickly perform calculations without needing specific expertise in the underlying science. The algaeMetrics calculator provides users with

a simple, Microsoft Excel data template in which to input stream data. This file is then uploaded to a SCCWRP-hosted website for processing, with results returned to the user almost instantaneously in a new Excel file. These calculations would otherwise require a thorough reading of complex technical documents and research articles, followed by development of complex calculations within the user's own software programs.

Seasonal climatologies of oxygen and phosphates in the Bering Sea reconstructed by variational data assimilation approach

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Abstract

Climatological fields of dissolved oxygen and phosphates in the Bering Sea during the spring, summer, and fall seasons were generated on the basis of an extensive dataset of hydrochemical observations (16, 356 stations, beginning in 1928) and a novel 3D variational algorithm for interpolation of a passive ocean tracer. The resulting patterns comply with maps produced earlier using an optimal interpolation method, though they also provide more detail and contain no "missing data" regions. Vertical spatial, and temporal variability of both parameters follow large-scale patterns of circulation, upper mixed layer depth, and phytoplankton productivity in the Bering Sea.

Citation

Panteleev, G, V Luchin, NP Nezlin, T Kikuchi. 2013. Seasonal climatologies of oxygen and phosphates in the Bering Sea reconstructed by variational data assimilation approach. *Polar Science* 7:214-232.

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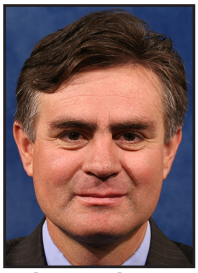

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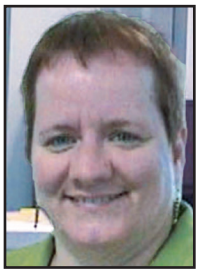

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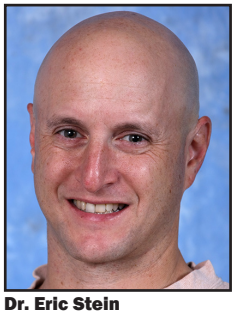

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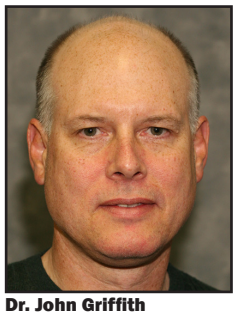

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Ken Schiff	California Water Quality Monitoring Council Southern California Stormwater Monitoring Coalition, Executive Committee Co-Chair State Water Resources Control Board, Biological Objectives Steering Committee
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Dr. Eric Stein	Bay Area Wetlands Regional Monitoring Program, Science Advisory Group California Wetland and Riparian Area Protection Policy, Technical Advisory Committee California Wetland Monitoring Workgroup Central Coast Wetlands Group, Advisory Committee Southern California Wetlands Recovery Project, Science Advisory Panel State Water Resources Control Board, Hydromodification Assessment Technical Workgroup California Healthy Streams Partnership, Advisory Team
Dr. Steve Steinberg	West Coast Governors Alliance, Data Action Coordination Team Co-Chair California Coastal and Marine Geospatial Working Group California Water Quality Monitoring Council, Data Management Workgroup Co-Chair
Dr. Martha Sutula	West Coast Ocean Acidification and Hypoxia Science Panel Pacific Marine and Estuarine Fish Habitat Partnership, Science and Data Committee Louisiana Coastal Protection and Restoration Authority, Advisory Panel on Diversions for the Mississippi River and Atchafalaya Basins California Cyanobacteria Harmful Algal Blooms Network, Technical Advisory Committee San Francisco Bay Nutrient Management Strategy, Technical Advisory Team Southern California Wetland Recovery Project, Science Advisory Panel
Dr. Steve Weisberg	California Clean Beach Task Force California Ocean Protection Council, Science Advisory Team West Coast Ocean Acidification and Hypoxia Science Panel California Ocean Science Trust, Board of Trustees California Water Quality Monitoring Council California Current Acidification Network, Steering Committee Chair Southern California Ocean Observing System, Governing Board

Local and Project Advisory Committees

Steve Bay	Los Angeles River Metals Total Maximum Daily Load Site Specific Objectives, Technical Advisory Committee San Francisco Estuary Institute, Toxicity Workgroup Santa Monica Bay Restoration Commission, Technical Advisory Committee Vice-Chair
Dr. John Griffith	Tecolote Creek Quantitative Microbial Risk Assessment, Technical Advisory Committee
Dr. Keith Maruya	San Francisco Estuary Institute, Emerging Contaminants Workgroup Scripps Center for Oceans and Human Health, Advisory Team
Dr. Raphael Mazor	Bay Area Regional Monitoring Coalition, Technical Advisor Los Angeles and San Gabriel Rivers Watershed Monitoring Program, Technical Advisory Committee
Ken Schiff	San Diego Integrated Regional Watershed Management Data Management Project, Advisory Committee King County (Washington) Water Quality Advisory Committee
Dr. Ashmita Sengupta	Santa Margarita River Low-Impact Development Implementation Study, Technical Review Committee
Dr. Eric Stein	Santa Monica Bay Restoration Commission, Technical Advisory Committee Ballona Wetland Restoration, Scientific Advisory Committee Colorado Lagoon Mitigation Banking, Technical Advisory Committee Ormond Beach Wetland Restoration, Technical Advisory Committee San Diego County Water Quality Equivalency, Technical Advisory Committee Upper Santa Ana River Habitat Conservation Plan, Hydrology Technical Advisory Committee
Dr. Martha Sutula	Elkhorn Slough Tidal Wetland Project, Water Quality Working Group Malibu Lagoon Restoration, Technical Advisory Committee Newport Bay Naturalists and Friends, Research Committee Ormond Beach Wetland Restoration, Technical Advisory Committee Tijuana River Estuary Restoration, Technical Advisory Committee Sea Grant Experimental Fish Enhancement Program, Science Advisory Panel
Dr. Steve Weisberg	San Francisco Estuary Institute, Exposure and Ecological Processes Workgroup

Scientific Societies

Steve Bay	American Water Works Association, Echinoderm Fertilization and Development Standard Method Joint Task Group Chair Society of Environmental Toxicology and Chemistry, Sediment Advisory Group Steering Committee Water Environment Research Federation, Trace Organics Eco-Risk Steering Committee
Dr. Yiping Cao	Southern California Chinese American Environmental Protection Association, Board of Directors
Dr. Meredith Howard	Harmful Algal Bloom Conference, Conference Co-Chair
Dr. Raphael Mazor	California Chapter of the Society for Freshwater Science, Secretary
Dr. Karen McLaughlin	California Estuarine Research Society, Treasurer
Dr. Alvina Mehinto	Society of Environmental Toxicology and Chemistry, North America Awards and Fellowship Committee Society of Environmental Toxicology and Chemistry, Southern California Chapter Toxicity Assessment Group
Shelly Moore	Southern California Academy of Sciences, Board of Directors, Webmaster, Annual Meeting Planning Committee

Dr. Eric Stein	Society of Wetland Scientists, Western Chapter Past President Society of Wetland Scientists, Wetland Concerns Committee
Dr. Steve Steinberg	Urban and Regional Information Systems Association, Southern California Chapter Board Member and California GIS Conference Planning Committee and Program Co-Chair American Society for Photogrammetry and Remote Sensing, Southwest Region Past President American Society for Photogrammetry and Remote Sensing, Pacific Southwest Region Regional Director California Geographic Information Association, Board Member
Dr. Martha Sutula	California Estuarine Research Society, President Coastal and Estuarine Research Federation, Governing Board
Dr. Doris Vidal-Dorsch	Society of Environmental Toxicology and Chemistry, Global Membership Committee Society of Environmental Toxicology and Chemistry, North American Membership Committee Chair Society of Environmental Toxicology and Chemistry, Transcriptional Advisory Goup Co-Chair
Dr. Steve Weisberg	Coastal and Estuarine Research Federation, Finance Committee Western Association of Marine Laboratories, President-Elect American Water Works Association, Biological Examination Standard Methods Committee

Editorships

Dr. Keith Maruya	*Chemosphere*, Associate Editor
Ken Schiff	*Marine Pollution Bulletin*, Editorial Board
Dr. Eric Stein	*Wetlands*, Editorial Board
Dr. Doris Vidal-Dorsch	*Journal of Coastal Development*, Editorial Board

University Committees

Ken Schiff	California State University, Fullerton, Dean of Natural Sciences Advisory Council
Dr. Doris Vidal-Dorsch	Oregon Sea Grant, Proposal Review Committee
Dr. Steve Weisberg	University of California Sea Grant, Advisory Council University of Southern California Sea Grant, Advisory Board Chapman University, School of Earth and Environmental Science Advisory Council

Thesis and Dissertation Committees

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Dr. Steve Steinberg	Master's Committee, Abel Santana, California State University, Long Beach
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