SCCWRP
2015 ANNUAL REPORT

Better, faster, cheaper

New molecular technologies revolutionize methods for detecting microbial contamination in coastal waters

SCCWRP Established 1969

Southern California Coastal Water Research Project
A Public Agency for Environmental Research

Welcome to the interactive version of SCCWRP's 2015 Annual Report! Click on the links below to jump directly to specific areas of the report. To request a printed copy of this report, contact pubrequest@sccwrp.org.

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SCCWRP 2015 ANNUAL REPORT

INTRODUCTION

FEATURE ARTICLES

Southern California's beach waters are routinely monitored for unsafe levels of waterborne pathogens. SCCWRP is working to develop better, faster, cheaper strategies and technologies for detecting this microbial contamination. **Page 21**

Southern California Coastal Water Research Project 2015 Annual Report

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Cover Photo
SCCWRP's Meredith Raith samples ocean water at Doheny State Beach in Orange County to test for microbial contamination that could pose a threat to beachgoers.

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ACCOMPLISHMENTS WITH JOURNAL ABSTRACTS

PEOPLE

Director’s Message

How do we measure success?

Since entering my Ph.D. program at the University of Delaware some 40 years ago, I have been searching for answers about what it means to achieve success as a scientist. We can all relate to the most obvious benchmarks of success, such as being awarded research grants and publishing in peer-reviewed journals. But SCCWRP’s niche in the water-quality management community demands more comprehensive measures of success. To that end, this year for the first time, we are using our Annual Report to lay out the metrics we use to judge our scientific success. I encourage you to spend time lingering over our Snapshot of Success to appreciate the many ways we define success as an aquatic science research organization.

Our vision of success is not something that our management team dreamed up overnight. Rather, it is the culmination of years of pondering our unique role within the water-quality management community, and then figuring out how to develop metrics that would help our scientists maximize their impact at SCCWRP. It also reflects how my own understanding of scientific success has evolved through the decades.

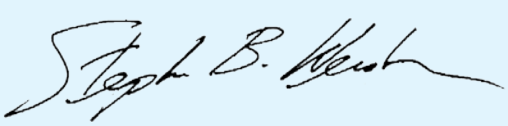
As a young scientist, my main goal was to build a reputation by publishing prolifically. Scientific journals use a peer review process to ensure the underlying research is rigorous, logical, and properly documented; thus, a high publication rate is a gold standard of success in science. At SCCWRP, we track and incentivize our scientific staff’s publication rate to ensure the organization is fostering credibility among scientific peers.

As my own body of published work expanded over the years, I began to look past the number of publications and focus more on whether others were reading and citing my work in their own articles and reports. Citation rate reflects how others are being influenced by our research and is thus another important measure of success at SCCWRP.

When I arrived at SCCWRP in the mid-1990s, I became clued into another metric of success that hadn’t been on my radar as a younger scientist: Developing scientific consensus around key ideas and concepts. SCCWRP’s governing board quickly impressed upon me that water-quality managers are not going to make sweeping management decisions and take costly actions based on one scientist’s – or even one organization’s – work. Hence, one of SCCWRP’s goals is to identify where scientific consensus does not exist and where it needs to be forged. As such, SCCWRP is proactive in fostering workshops, meetings and research collaborations that bring scientists together to discuss, debate and synthesize their work.

Most importantly, during my time here at SCCWRP, I have come to appreciate the way we are uniquely positioned to transition new scientific ideas and technologies into applications that can be used by water-quality managers and decision-makers. The SCCWRP Commission and the Commission’s Technical Advisory Group (CTAG) help us every day to focus our research on issues of managerial relevance and determine when, if and how those research products can be put into practical application. In the end, all of the metrics that help us achieve scientific credibility and create a collaborative environment for achieving scientific consensus are just waypoints along the path to effective management use of our science; our ultimate goal is the adoption of our work by our member agencies. This metric is harder to quantify, but the four feature articles in our 2015 Annual Report were selected to provide examples of where we have succeeded in transitioning new tools into application, thereby enhancing the scientific foundation for management decision-making.

I look forward to receiving your feedback on how we can continue to refine our vision of scientific success to best meet the needs of the water-quality management community we serve.



Stephen B. Weisberg, Ph.D.
Executive Director

Snapshot of Success

How SCCWRP worked to improve aquatic science research and water-quality management in 2015

SCCWRP stepping stones to success

Step 1: Establish and maintain credibility with colleagues in the aquatic science community

Step 2: Promote consensus-building through scientific collaboration and leadership

Step 3: Transition science effectively to the end-user water-quality management community

Step 4: Provide technical support to the organization's 14 member agencies to maximize their use of science

What SCCWRP seeks to achieve

» Translate aquatic science research into management applications

» Optimally position the water-quality management community to benefit from scientific research

» Positively influence how aquatic systems are managed in Southern California and beyond

1 Scientific credibility

For SCCWRP to effectively transition science to application, SCCWRP must first establish and maintain credibility with scientific peers. SCCWRP uses two primary metrics to quantify success in this area:

» Publication rate

Publishing prolifically in scientific journals is an important measure of scientific success, as these articles go through a rigorous peer review process. A robust publication rate engenders credibility for SCCWRP in the broader scientific community.

Accomplishment
SCCWRP scientific staff published an average of **3.2** journal articles each per year over the past three years. This compares favorably with the **2** publications per year minimum that SCCWRP's partners at academic research institutions generally seek to achieve when being considered for promotion.

» Citation rate

Whereas the number of publications quantifies productivity, citation rate provides a measure of how widely read SCCWRP's work is and the degree to which it is influencing other scientists. SCCWRP's goal is for other scientists to reference SCCWRP's work when publishing their own.

Accomplishment
SCCWRP publications were cited **23%** more frequently in 2015 than the average for the aquatic sciences discipline, and **2.6%** of SCCWRP publications in 2015 appeared in the top 1% of all articles cited in the aquatic sciences.

2 Scientific consensus-building

The most expeditious path for the management community to incorporate scientific findings into decision-making is for scientists to achieve consensus. SCCWRP facilitates consensus-building through:

» Leadership

Attaining leadership roles with professional scientific organizations enhances SCCWRP's opportunities for interactions and consensus-building in the aquatic sciences.

Accomplishment
See Page 68 for a listing of SCCWRP's leadership roles with professional societies, editorial boards of scientific journals, and scientific advisory committees in 2015.

» Collaboration

External interactions, especially in leadership capacities, often translate to collaborative scientific publications. The number of external organizations with which SCCWRP coauthors scientific articles is a reflection of SCCWRP's success in building consensus.

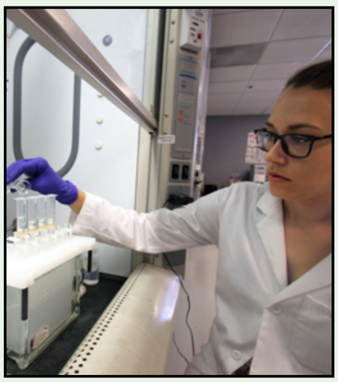
Accomplishment
SCCWRP published scientific articles and reports with **109** different institutions in 2015.

3 Management adoption

Scientific credibility and consensus-building are important waypoints along SCCWRP's journey toward producing science that is adopted and used by the water-quality management community. The four feature articles in this report demonstrate SCCWRP's successes in:

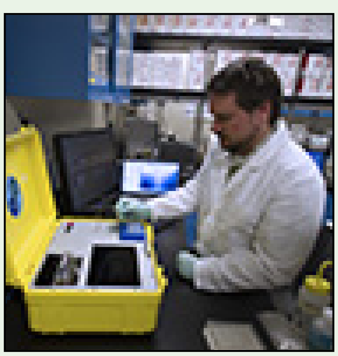
Accomplishment
Giving Southern California's hydromodification managers the strategies and tools they need to prevent and mitigate erosion **Page 5**

Accomplishment
Developing a monitoring framework that allows California water-quality managers to identify and track contaminants of emerging concern **Page 11**



Accomplishment
Helping California stream managers to understand how human activity affects in-stream biological communities **Page 16**

Accomplishment
Developing faster, cheaper, more reliable strategies and technologies for protecting the health of beachgoers who enter coastal waters **Page 21**

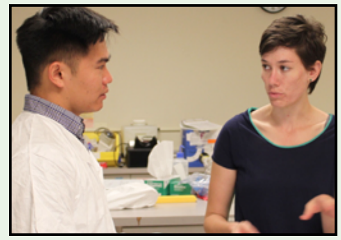


4 Implementation support

While achieving adoption of new science is a signature SCCWRP accomplishment, SCCWRP maximizes the effectiveness of transitioning science to management by providing continuing implementation support.

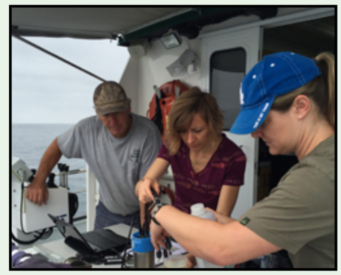
» Training

The initial transfer typically involves preparing user-friendly instructional materials and/or conducting hands-on training.



» Intercalibration

Next, SCCWRP typically facilitates intercalibration and quality-assurance exercises to aid others in demonstrating proficiency.

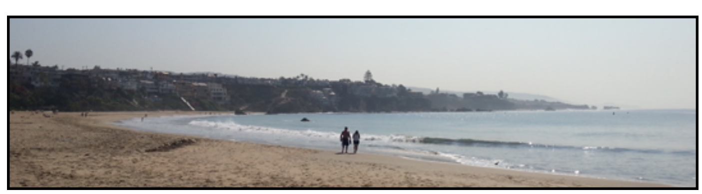


» Rollout

Finally, full-scale implementation typically involves case studies and formation of advisory committees, in which SCCWRP scientific staff provide counsel and expertise to member agencies to support successful rollout and refinement.

SCCWRP prides itself on its collaborative relationships with member agencies through all of these implementation steps.

Accomplishment
SCCWRP staff spent more than **10,000** person-hours in 2015 providing implementation support to its 14 member agencies.



HALTING HYDROMODIFICATION

The quest to eliminate erosion in Southern California's built environment

As Southern California development exploded over the 20th century and fundamentally altered how rain water moves across landscapes, minimal attention was paid to the environmental consequences.

Although dense construction projects quickly enveloped natural flood plains and cut off routes for stormwater runoff, developers and municipal planners solved these problems by building an extensive network of storm drains and channels to efficiently carry rain water away from developed surfaces.

Meanwhile, as high volumes of stormwater runoff inundated natural rivers and streams, officials responded by lining them with concrete, ensuring their utility as part of Southern California's massive flood control infrastructure.

SCCWRP's Dr. Eric Stein measures the depth of Borrego Wash, an eroding creek in southern Orange County just downstream from a residential development. Over a three-year period, hydromodification-related forces lowered the creekbed by about 2 feet.

These relentless modifications to Southern California's landscape carried a heavy ecological price tag: Not only did Southern

A nursery greenhouse perches precariously atop an eroded bluff in Oso Creek in southern Orange County. Although water levels in the creek do not reach the greenhouse itself, the base of the creek walls have been eroded, causing the earth above to give way.

Californians lose out on the aesthetic and recreational benefits provided by natural streams and rivers, but plant and animal communities were severely altered.

"Flood-control officials used to view our natural streams and rivers as conveyances for stormwater runoff, but that really is not the only function our water corridors can provide," said Dr. Eric Stein, a watershed ecologist who heads SCCWRP's Biology Department. "As a society, we've realized they offer multiple ecological and societal benefits."

Over the past decade, municipal planners and water-quality regulators have placed progressively greater emphasis on developing environmentally responsible approaches for managing stormwater runoff – approaches that do not include simply paving over nature.

Today, when Southern California developers propose construction projects, they are obligated to engineer solutions that minimize the ways that developments alter the flow of stormwater across a site, and that reduce the ecological and water-quality impacts of those altered flow patterns.

To achieve these goals, the stormwater management community relies on hydromodification science, which is the science of how changes in land use trigger changes in runoff patterns that can result in modifications to the physical environment.

SCCWRP has facilitated a team of scientists over the past decade who have helped construct the strategies and approaches that hydromodification managers use to evaluate how development and other changes in land use affect runoff, how channels respond to these changes in runoff, and how to best minimize or mitigate these impacts.

"We've been working to not only help water-quality regulators, municipalities and private developers understand the risks of erosion and the associated degradation of habitats at the specific site level, but also how to come up with strategies and approaches that will mitigate these impacts," Stein said.

In 2015, San Diego County became the first in Southern California to roll

Did you know?

Development and redevelopment projects in Southern California typically require that all runoff from storms up to and including the 85th percentile storm be physically retained on site for 24 hours or allowed to infiltrate naturally into the ground. These strategies improve water quality, but do not completely eliminate the hydromodification threat. An 85th percentile storm is a storm that is more intense than 85% of the storms to hit the region.

out an innovative program, based in part on SCCWRP science, that allows developers in the county to comply with hydromodification-related requirements at a site other than their own development site. Under the San Diego County Offsite Alternative Compliance Program, developers can choose to install a hydromodification management solution somewhere else in the watershed that provides a greater overall benefit to ecological health.

"SCCWRP helped us expedite the development of this program by already having done the research that's allowed us to move in this direction," said Sheri McPherson, project manager for San Diego County's Watershed Protection Program. "There's really nothing out there like this program at this point."

Hydromodification in Southern California can trigger sudden, dramatic changes to the landscape, as seen in these before and after photos from a single 2007 rainstorm in Hasley Canyon Creek in northern Los Angeles County. Although just 0.3 inches of rain fell, portions of backyards that back up to the creek fell into the creekbed. The area is not densely populated, but the change in impervious cover from the residential development triggered creek erosion and eventually caused the banks to collapse.

The importance of impervious cover

The underlying reason new development heightens the risk of erosion comes down to a concept known as impervious cover. Impervious cover is the increasingly large portion of the ground that becomes impermeable to rain water as buildings and roads are constructed.

Over time, as infrastructure envelops undeveloped areas, stormwater has increasingly less square footage to meander across as it barrels toward rivers and streams, and/or soaks naturally into the ground. Consequently, this water tends to run off the land with far greater ferociousness.

The impervious cover for an average residential development with eight homes per acre hovers around 33%, while the average commercial zone has an impervious cover of about 72%. Even parks and other open land in urban areas can have impervious covers above 10%.

During early work on hydromodification more than a decade ago, SCCWRP and its collaborators demonstrated that increasing impervious cover by as little as 3% or 4% could dramatically heighten the intensity of erosive forces on Southern California's natural streams and other channels.

The reason is twofold: First, Southern California watersheds tend to have especially soft, sandy compositions that make them more prone to erosion. Second, Southern California tends to be characterized by sporadic and intense rainfalls, steep and dramatic topography that can have big impacts on runoff flow rates, and naturally wide flood plains that have been severely constricted through development.

This finding was significant because for more than a decade prior, Southern California's hydromodification management community was working under the assumption that the most damaging impacts of hydromodification would not be felt until about 25% impervious cover was reached.

The 25% threshold was based on a seminal 1994 report released by the Maryland-based Center for Watershed Protection that suggested that an impervious cover of 25% marked an ecologically significant tipping point.

Consequently, prior to the mid-2000s, Southern California stormwater management officials

Integrated hydromodification management

This framework is a simplified version of the conceptual framework used by the hydromodification management community to improve outcomes for streams and other channels vulnerable to damage from flowing stormwater.

ASSESSMENT
Conduct a watershed assessment
Consider:
- Physical characteristics and hydrological processes
- Past, present and future land uses

GOAL-SETTING
Determine what you're trying to achieve
Consider:
- Protection, restoration and management goals
- Opportunities and constraints

IMPLEMENTATION
Develop implementation strategies
Consider:
- Permit/regulatory requirements
- Overall watershed health

EVALUATION
Assess effectiveness using tiered monitoring framework
Consider:
- Does it perform as expected?
- Is it having the desired effectiveness?
- What happens across space and over time?

Above, a formerly shallow creekbed that runs through a housing development in Acton has eroded to a depth of about 10 feet over the course of a decade. The rural housing development, left, in satellite view, introduced an impervious cover to the watershed of only about 3% when it was built in the 1990s, but this change was enough to trigger dramatic erosive impacts to the landscape.

imposed comparatively modest hydromodification design standards on new construction and redevelopment projects.

Today, by contrast, stormwater managers impose stringent hydromodification-related design standards on developers, cognizant that Southern California is far more susceptible to small changes in impervious cover than other parts of the country.

"Before our hydromodification research program, people were surprised that channels were still eroding and we weren't able to maintain robust aquatic biological communities," Stein said. "The problem was that we were making assumptions about impervious cover that simply did not apply to Southern California."

Improving hydromodification management

In the footsteps of SCCWRP's early work on hydromodification management strategies, municipalities and state water-quality regulators began setting more stringent design standards intended to offset impervious-cover impacts.

By 2010, construction permits were being issued to developers specifying that their development and redevelopment projects could not cause any net increase in the erosive potential of the channel.

To comply with these requirements, developers have adopted a wide variety of engineering solutions, commonly known as best management practices (BMPs). These BMPs fall into four main categories:

SCCWRP toolbox

SCCWRP has developed a suite of hydromodification management tools over the past decade that are instrumental in assessing the effectiveness of hydromodification management plans:

Tools to characterize extent of effect and channel condition

Analytical regime diagrams: Detailed maps that predict how changes in water/sediment discharges will alter channel dimensions

Channel evolution model: Updated version of a model that predicts how channels will respond over time to hydromodification

Field screening tool: Statistical tool for assessing relative susceptibility of channels to hydromodification

Regional hydrologic curves: Region-specific graphs that predict how much stormwater is expected to be produced by catchments of different sizes

Tools to predict likely channel response to changes in land use or management actions

Channel enlargement models: Statistical models that use region-specific data to predict how channels will grow in size in response to hydromodification

Artificial neural network model: Mathematical model that predicts changes to a channel's cross-sectional area based on multiple variables

Sediment yield analysis: Geospatial tool that predicts how much sediment will be transported from a given site

Planning and monitoring tools

Decision-support tools: Matrices that help hydromodification managers select from multiple viable courses of action

Monitoring framework: Guidance parameters for setting up a site-specific monitoring program for a hydromodification management program

» **Land-planning strategies:** Developers can identify opportunities to shift around the planned locations of buildings and other infrastructure in ways that minimize how the buildings will disrupt the flow of water running off the site. For example, when developers build more homes on hard, rocky surfaces that are already impervious to stormwater, the overall increase in impervious cover is less

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than if more of those homes were built on softer, water-permeable ground.

» **Low-impact developments:** Developers can pursue a number of environmentally friendly, engineered solutions known as low-impact developments to offset the impervious-cover footprint of a new construction project. Low-impact developments include installing pavement that is permeable to water, or diverting stormwater into bioswales where stormwater can infiltrate gradually and naturally into the ground.

» **Retention strategies:** Developers can build physical structures on their project site to detain or retain stormwater runoff. These basins can collect large volumes of runoff and then release it gradually, allowing runoff patterns to more closely mimic flow patterns prior to development.

» **Channel and floodplain restoration and rehabilitation:** Developers can protect channels from erosion through a variety of restoration and rehabilitation practices, including widening channels, stabilizing through bioengineering, and reconnecting channels with their historic floodplains. These practices not only serve to reduce erosion, but also can restore how aquatic ecosystems historically functioned.

To ensure that the hydromodification management solutions proposed by a developer will achieve their intended objectives, county planning officials who issue development permits use a set of standard computer-based tools and predictive modeling relationships developed by SCCWRP and others. This scientific toolbox allows all parties to reach agreement on appropriate management measures that should be taken to minimize hydromodification-related impacts.

In recent years, SCCWRP has dramatically expanded the hydromodification management toolbox, adding tools tailored to meet Southern California-specific management needs. Today, many of SCCWRP's tools are explicitly called out in stormwater permits.

How hydromodification standards are set

The state's Regional Water Quality Control Boards prescribe hydromodification requirements to counties by issuing an MS4 permit containing stormwater runoff standards. Each county then works to interpret the standards, establishing a series of hydromodification management requirements for developers to ensure the county can remain in compliance with its MS4 permit.

Building next-generation management solutions

In 2015, San Diego County revamped its hydromodification management requirements to give developers the option to control for hydromodification off site, at a location in the watershed other than the development site itself.

The San Diego County Offsite Alternative Compliance Program, based in part on SCCWRP strategies and recommendations, gives developers the option to achieve compliance through installation of offsite solutions, such as regional detention facilities or a stream rehabilitation project somewhere else in the watershed.

"The bar for water quality has moved up, but now it's easier to meet that bar," said Charles Mohrlock, a civil engineer for San Diego County's Watershed Protection Program. "This alternate compliance option allows us to support development and redevelopment while providing a greater environmental benefit."

The alternative compliance program, which could become a model statewide, is a recognition that the effectiveness of onsite hydromodification management measures can be limited, and that allowing developers to engineer an offsite solution can result in a more positive net impact, with new opportunities to address hydromodification's complex impacts and to pool resources to pursue larger restoration efforts.

Although the first developer permits under this program could be awarded as early as 2016, technical and policy challenges remain, including the need to create a market-based

Portions of Forester Creek in San Diego County embody Southern California's legacy of lining natural streams with concrete to maximize their utility as flood control conveyances. Today, Southern California water-quality managers strive for more natural options that provide aesthetic and ecological benefits. Some areas of Forester Creek already have been restored to a more natural state.

currency system to track these offset transactions.

SCCWRP will continue to provide technical support, as well as work to improve effectiveness by evaluating lessons learned from San Diego County's first alternative compliance projects.

SCCWRP also is tackling the next frontier in hydromodification management: Flow ecology, which seeks to explain how efforts to improve management of stormwater flows intersect with efforts to protect the aquatic organisms that depend on these flows to sustain life.

In 2013, SCCWRP and its partners launched a three-year study using a scientific framework known as the Ecological Limits of Hydrologic Alteration, or ELOHA, to understand at what tipping point changes to water flows begin to degrade aquatic ecosystems. The ELOHA study findings will be released in phases beginning in 2016.

"Right now, the focus tends to be on the flow regime and measuring the physical features of streams," Stein said. "But to really know that streams are healthy, we need to ensure we're adequately protecting the plant and animal communities that depend on them. This is the ultimate endpoint of our hydromodification management work."

Scientists survey a manmade grade stabilizer in the middle of Borrego Wash in southern Orange County. The stabilizer, a solid structure made of cement and rocks, illustrates the challenges of hydromodification management. The stabilizer was built as a sort of dam to slow the flow of creek water, but it is now in danger of collapsing because of erosion on its underside. If the stabilizer were to collapse, it would send huge volumes of sediment trapped behind it rushing into the creekbed below.

A stream restoration effort in the mid-1990s has helped preserve the wide flood plain of the Santa Clara River in northern Los Angeles County. Hydromodification's erosive impacts are minimized when a stream is allowed to meander across its natural flood plain, dispersing water and energy.

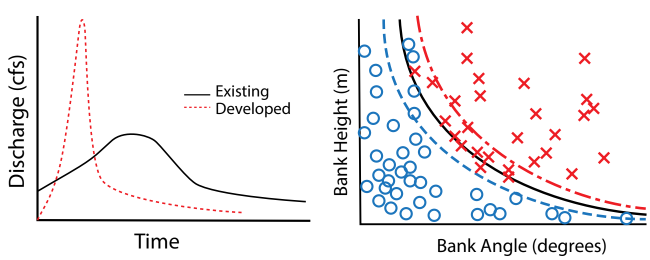
Permitting in the real world

To build or redevelop a site, developers are responsible for, among other things, creating a hydromodification management plan to limit changes to how stormwater flows across the site. This process typically plays out as follows:

1 Developer requests a plan check with the county to understand require-ments for managing stormwater runoff at the site.

2 Developer hires a consultant to engineer a plan for controlling excess stormwater runoff.

3 Consultant uses hydromodification management tools (including SCCWRP-developed tools) to assess the plan's effectiveness.



4 Consultant submits the plan to the county for a final plan check.

5 County verifies all requirements have been met and issues permit to the developer.

COMPREHENSIVE CONTAMINANT MONITORING

New management strategies and technologies expand chemical detection capabilities in California's aquatic environments

California's capacity for detecting chemical contaminants in aquatic environments has historically been developed on an incremental basis.

When state officials started monitoring for contaminants such as the pesticide DDT (dichlorodiphenyltrichloroethane) in the 1970s and the industrial chemical class known as PCBs (polychlorinated biphenyls) in the 1980s, scientists designed laboratory-based analytical tests that were specific to the chemical being measured.

Thus, as the list of chemicals grew, so did the time and cost associated with monitoring these chemicals regularly across California's diverse aquatic environments. Even as some chemicals on the list fell out of production and use, state and federal environmental regulations continued to require that the chemicals be monitored.

The highly urbanized Los Angeles River transports a variety of contaminants from the land to coastal waters.

Many of these chemicals can remain active for decades in aquatic environments, underscoring the value of ongoing monitoring programs. But at the same time, there are thousands of other chemicals in aquatic environments that are being produced by human activity that are not being monitored at all – or in very limited capacities.

These contaminants of emerging concern (CECs) include synthetic hormones, antibiotics, plasticizers and detergents, and they are being flushed down toilets, sinks and storm drains on a daily basis. They also can be washed off the land by rain, and some of these CECs can evade water treatment processes and make their way back into potable water supplies.

"CECs have historically been the elephant in the room, because we always knew they were there, but we didn't have the technology and the science to measure if they were having any adverse effects on us or the environment," said Dr. Keith Maruya, an environmental chemist who leads SCCWRP's CEC research efforts.

Today, scientists understand that fish and other aquatic life can experience health impacts when they are exposed to certain CECs, even at low concentrations. And scientists also recognize that the traditional, chemical-specific approach to

Common CECS found in aquatic environments

Pesticides: Bifenthrin, permethrin, chlorpyrifos

Consumer products: Bisphenol A, diclofenac, galaxolide, ibuprofen

Natural hormones: 17beta-estradiol, estrone

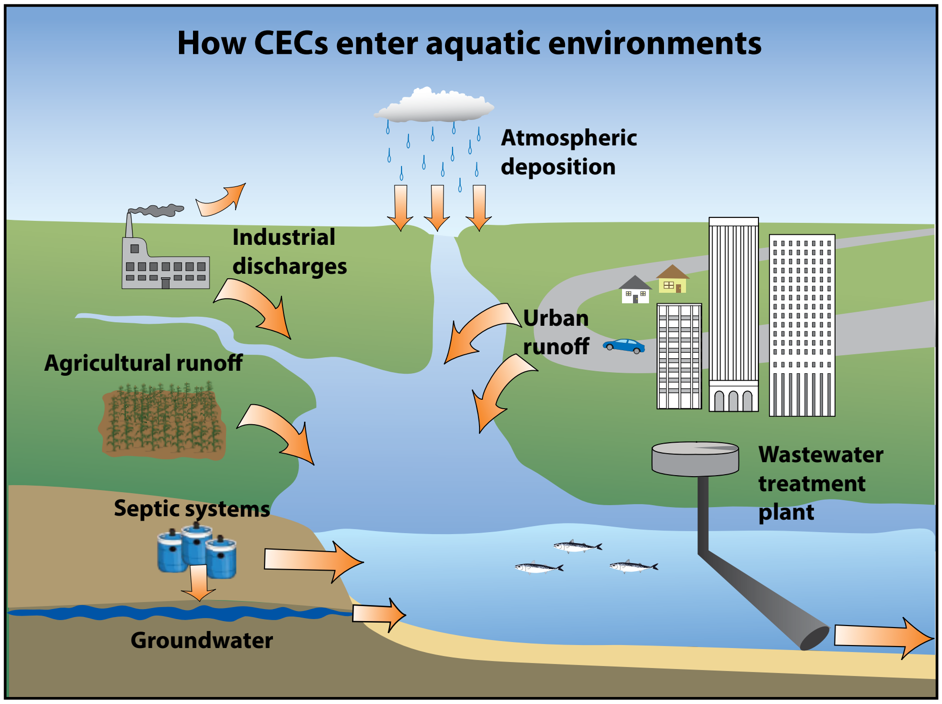
Antibiotics: Triclosan

Plasticizers: Bis-2-ethylhexyl, butylbenzyl phthalates

Flame retardants: Polybrominated diphenyl ethers 47, 99

Detergents: 4-nonylphenol

Industrial products: Perfluorinated chemicals (e.g., PFOS)



contaminant monitoring developed in the late 20th century cannot be scaled up or adapted to monitor the thousands of CECs and their breakdown derivatives in the chemical universe.

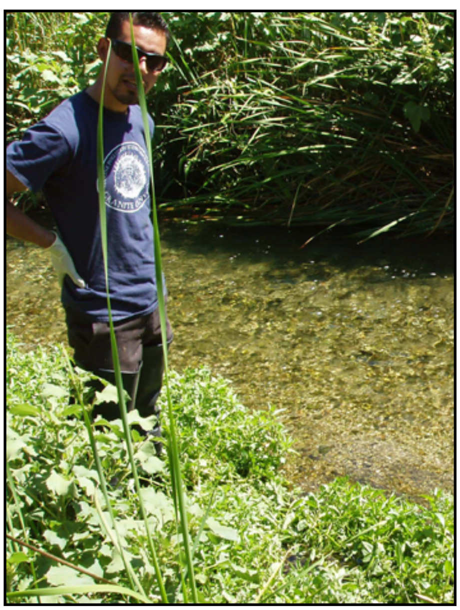
In 2009, cognizant of these challenges, the State Water Board asked a scientific advisory panel to develop recommendations for overhauling California's chemical monitoring programs.

The seven-member panel, which was convened and facilitated by SCCWRP, recommended a long-term CEC management strategy designed to help water-quality managers zero in on the CECs that pose the greatest potential risks to humans and ecosystems, in the most efficient, cost-effective manner possible.

The strategy – encapsulated in a statewide CEC management framework unveiled by SCCWRP in 2015 – takes advantage of recent advances in cellular bioassays and "nontargeted" analytical chemistry to comprehensively screen water samples from any aquatic system. This monitoring strategy is designed to work even as the universe of CECs changes over time.

"We wanted a framework that will work in perpetuity, that will be relevant even as new chemicals go into production and use over time while others get phased out," Maruya said.

In 2015, SCCWRP began transitioning this updated, modernized CEC monitoring framework to California's water-quality management community for pilot evaluation. The Southern California Stormwater Monitoring Coalition has been testing the framework as part of its ongoing Regional Watershed Monitoring Program, and the North Coast Regional Water Quality Control Board in Santa Rosa launched a three-year pilot study in 2015 to test SCCWRP's framework in the Russian River watershed.



Hector De Haro from the Sanitation Districts of Los Angeles County's San Jose Creek Laboratory collects water samples in the Santa Clara River in Los Angeles County during a 2013 CEC monitoring study commissioned by the Los Angeles Regional Water Quality Control Board.

"We recognize the importance of the tools in SCCWRP's framework," said Rich Fadness, an engineering geologist for the North Coast Regional Water Quality Control Board and the region's Surface Water Ambient Monitoring Program coordinator. "Pesticides are changing all the time, and there's so much we don't know about what's going on here. This framework offers us an opportunity to grab at that."

Monitoring CECs presents unique challenges

Monitoring CECs in aquatic environments is a far more difficult endeavor than the traditional chemistry-based approaches used to monitor drinking water and other water sources.

Drinking water agencies in California, for example, screen potable water supplies against a defined list of about 100 chemicals. If the concentration of any of these chemicals is too high, there are defined management processes in place to bring the concentration back down to a level deemed safe for human consumption.

By contrast, the CEC universe encompasses thousands of chemicals, many of which go entirely undetected through traditional monitoring methods and whose health risks are poorly understood. California has some guidelines in place for monitoring select CECs, but the CEC expert panel found that these monitoring processes were neither fully articulated nor all-encompassing.

"For every CEC that water-quality managers have developed a specific chemical method to use for monitoring, there are thousands more CECs that go entirely undetected or whose health risks are poorly understood," said CEC panel member Dr. Daniel Schlenk, a professor of aquatic ecotoxicology at the University of California, Riverside.

CECs originate from a wide variety of sources. They are found in processed foods, personal hygiene and cosmetic products, medications, car exhaust, pesticides, and industrial discharges, among other sources.

And they are transported to aquatic environments through equally varied means, including stormwater runoff, wastewater effluent discharges, leaking sanitation infrastructure, and atmospheric deposition.

Most CECs are removed during drinking-water and wastewater treatment processes, but there is no comparable safeguard for natural aquatic environments: When it rains, thousands of CECs can wash off the land and into coastal waters and other waterbodies, typically with very limited or no treatment.

CECs are considered an "emerging concern" because recent advances in detection methods have brought their occurrence to the forefront, even as their impacts to ecological and/or human health remain largely unknown.

Over the past decade, scientists have begun to amass data on the classes of CECs that tend to be most harmful to humans and wildlife. One class of CECs that has been extensively studied is synthetic chemicals that mimic the effects of sex hormones. A variety of prescription drugs, including birth control pills and hormone-infused ointments, contains sex hormones such as estrogen, androgens and progesterone.

Implications of water recycling

Recycled water in California is often used to irrigate landscapes and crops, or to boost groundwater levels through direct injection. While these practices can help manage limited water supplies, scientists and water-quality managers need more effective screening tools to detect CECs in recycled water and to evaluate the potential health risks posed by CECs.

The concern is that when humans excrete these chemicals in urine and feces, they are not fully removed during wastewater treatment. Thus, when they're discharged into receiving waters and fish and other aquatic life come into contact with them, the chemicals can have damaging effects on reproduction, growth and survival rates.

"Robust CEC monitoring programs need to be able to identify unexpected contaminants like estrogen-mimicking chemicals as soon as they appear," said Dr. Nathan Dodder, a senior chemist at SCCWRP. "We need a comprehensive, multi-pronged approach to do this."

Panel's initial focus on CECs in recycled water

SCCWRP began working in earnest to understand the potential health threats posed by CECs in 2009, when the State Water Board asked SCCWRP to convene a scientific panel of six experts in chemistry, toxicology, engineering and risk assessment to make recommendations for CEC monitoring and management in California.

The panel grew out of a call by Gov. Arnold Schwarzenegger to boost water conservation measures amid a statewide drought in 2009. Among the governor's key priorities was a focus on recycling more water for potable reuse – a push that was subsequently codified in the Water Conservation Act of 2009.

State Water Board officials recognized that if more recycled water was going to be used for applications

Santa Rosa's Spring Lake is being evaluated by water-quality officials as part of a three-year study examining what types of CECs are entering the Russian River watershed from land-based sources.
Courtesy of Marine Pollution Studies Laboratory

like irrigation and groundwater recharge, there would need to be improved scientific understanding of the potential health risks from CECs in recycled water – and how best to minimize those risks.

Almost immediately, it became clear to SCCWRP and the panel that the CECs present in recycled water aren't unique to recycled water, nor are humans the only living beings that can be affected by CECs.

Hence, SCCWRP teamed up with the David and Lucile Packard Foundation to expand the panel's charge to examine the ecological risks of CECs in California's aquatic ecosystems. A seventh panel member specializing in marine resources also was added.

Out of the panel's three years of deliberations evolved the scientific foundation for a modernized, updated framework for monitoring CECs across California's diverse aquatic environments.

Key to this monitoring framework are two emerging technologies that SCCWRP has been working on with collaborators from around the world for nearly a decade:

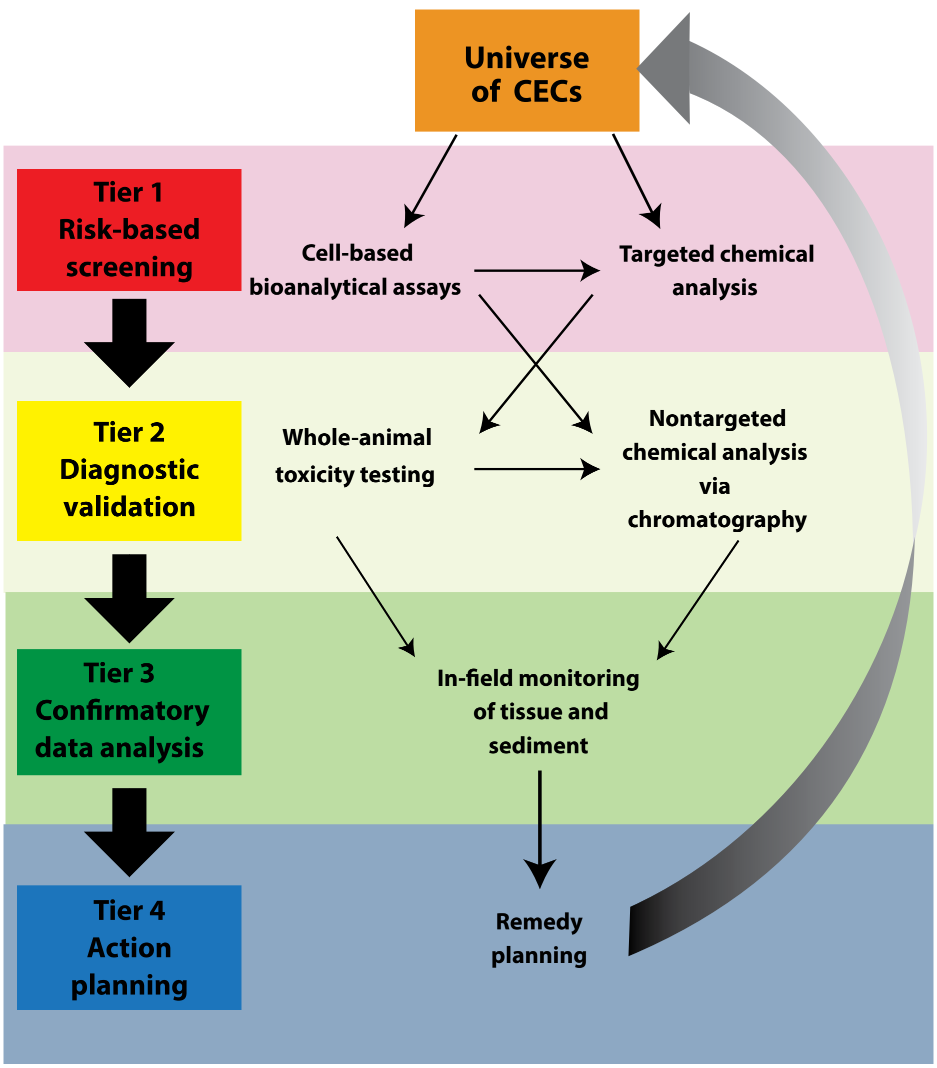
» **Bioanalytical screening assays:** This laboratory testing method involves exposing engineered cell lines to water samples to screen for toxicity. Cell-based assays, which are widely used in pharmaceutical and diagnostic medical applications, were first used in the environmental arena by agencies including the U.S. Environmental Protection Agency and the European Union's chemical registration program; the goal was to screen individual chemicals for toxicity. SCCWRP has been working with partners around the world, including in Australia and Europe, to adapt these commercially available assays to screen for any number of CECs that may be present in waterbodies.

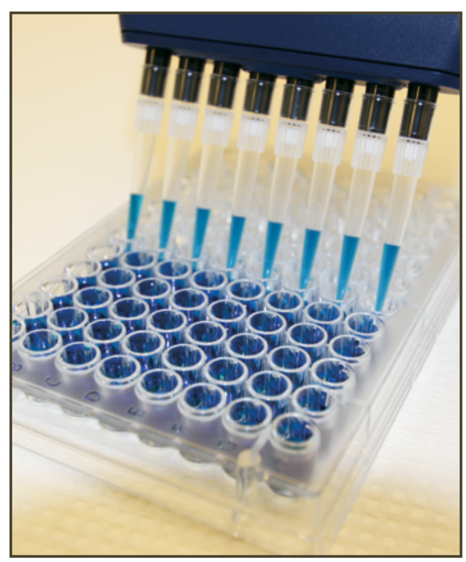
» **Nontargeted analysis:** This analytical chemistry technique involves the use of gas or liquid chromatography coupled to a rapidly scanning mass spectrometer to separate and then identify chemicals based on physical and chemical characteristics. Nontargeted analysis offers an opportunity to detect a broad range of individual compounds present in a sample, most of which would have gone undetected using conventional "targeted" analytical methods.

These bioanalytical screening and nontargeted technologies, which scientists are still working to unlock the full potential of, are designed to be

CEC monitoring framework

SCCWRP has developed a multi-tiered, adaptive management strategy for detecting and ascertaining the risks of CECs in the environment. Each tier becomes progressively more complex, lengthy and costly to execute, giving managers an efficient, cost-effective way to zero in on the CECs that pose the greatest potential health risks.



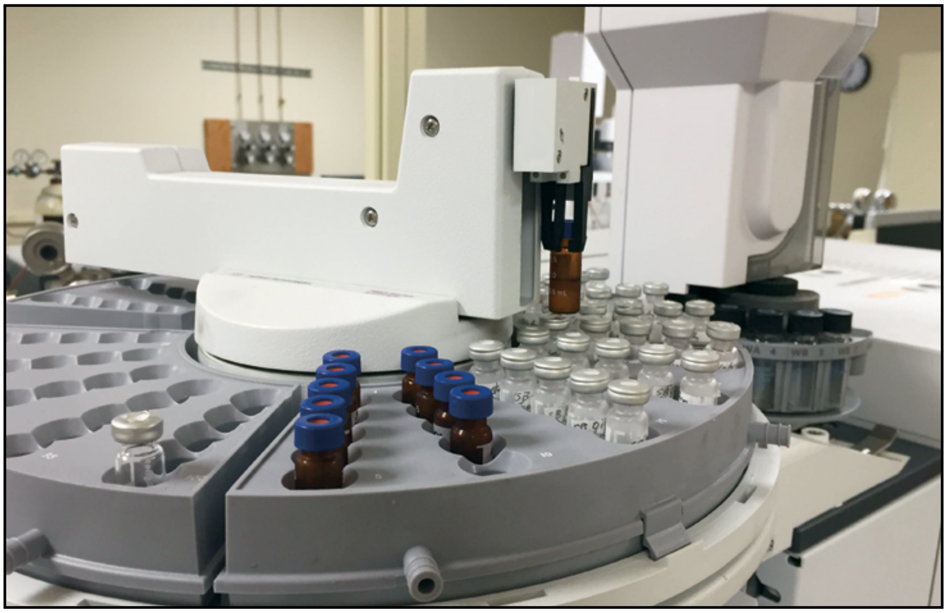


Bioanalytical screening involves the use of commercially available cell assays to detect potentially harmful CECs. SCCWRP and its collaborators have been working to adapt the technology for aquatic monitoring applications.

able to screen a much larger universe of CECs, while at the same time reduce the time, expense and scope of traditional monitoring methods, such as whole-animal toxicity testing and in-field monitoring.

Traditional approaches play an invaluable role in monitoring CECs, but they are labor- and time-intensive, and are not always able to conclusively state the cause of observed toxic effects, including what role CECs may have played.

"In-field monitoring through programs like the Southern California Bight Regional Monitoring Program are great for detecting the impacts of CECs on aquatic ecosystems, but in-field monitoring takes time – we cannot wait 10 years to know if the environment is suffering," said Dr. Alvina Mehinto, a molecular toxicologist at SCCWRP. "Plus, it's not realistic to think we could do field monitoring for all receiving waters statewide."

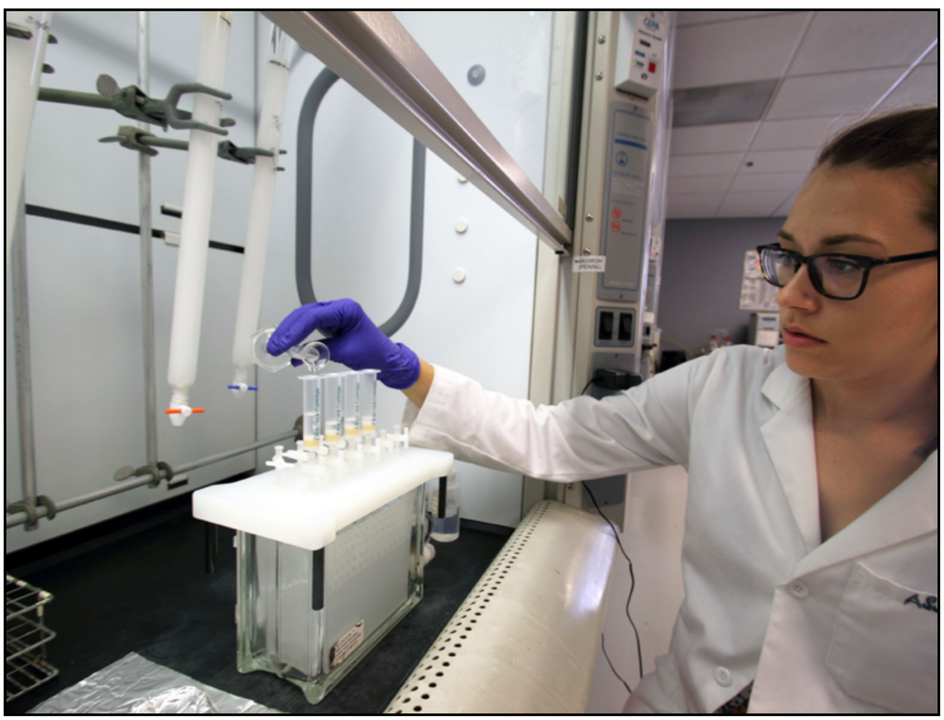


A gas chromatography machine separates chemicals based on physical and chemical characteristics in an analytical technique known as nontargeted analysis. Nontargeted analysis allows scientists to identify broad classes of chemicals present in water samples.

Pilot-testing the CEC monitoring framework

SCCWRP has been preparing to test the utility of the CEC monitoring framework for the past few years, conducting preliminary work with its member agencies, including the Los Angeles Regional Water Quality Control Board, Sanitation Districts of Los Angeles County, and City of Los Angeles Bureau of Sanitation, as well as regional monitoring entities like the San Francisco Estuary Institute.

In 2015, the Southern California Stormwater Monitoring Coalition began testing the framework as part of its ongoing Regional Watershed Monitoring Program.



SCCWRP's Darcy VanDervort prepares water samples to screen for the presence of endocrine-disrupting CECs via bioanalytical assay. Endocrine-disrupting CECs can interfere with the hormone systems of humans and wildlife.

Also in 2015, the North Coast Regional Water Quality Control Board kicked off a three-year study examining the framework's utility for monitoring CECs identified by the expert panel that run off the region's many vineyards and farmlands, as well as the treated wastewater effluent that gets discharged into the Russian River watershed during the rainy winter and spring months. The study involves tracking CECs in water, sediment and the tissues of fish as scientists work to develop a comprehensive list of pesticide chemicals that should be the focus of future monitoring.

The two ongoing pilot tests are designed to not only help water-quality managers get a better handle on the regional challenge posed by CECs, but also to demonstrate the value and effectiveness of the CEC monitoring framework anywhere in the state.

"What we really want to be able to do is show that you can do more meaningful traditional monitoring if you follow this framework first," Maruya said. "We believe the tools and screening strategies in the framework are the keys to being able to monitor CECs in all of California's waters, including the water that we reclaim for eventual potable use."

PAVING THE WAY FOR A NEW PARADIGM IN STREAM MANAGEMENT

The California Stream Condition Index, co-developed by SCCWRP, is the first statewide scoring tool for evaluating ecological health of streams; it solves persistent challenges associated with assessing California's diverse stream types

For more than a century, scientists have sought to use the biological diversity of organisms living in and around a stream as a way to assess overall ecological health.

The premise behind biological assessments, or bioassessment, is simple: Pollution and other human activities tend to impact the sensitive organisms living in a stream, altering both their population sizes and the types of species present. Some species flourish under this human-induced stress, while others dwindle or disappear.

But the reality of measuring the biological health of streams in a region as complex and varied as California is not so simple. Streams in the rugged, snow-filled mountains of the Sierra Nevada support wholly different biological communities than streams in the low-lying, semi-arid deserts of Southern California.

Consequently, environmental managers tasked with monitoring the health of California streams need to know what numbers and types of organisms they should expect to find at a given site.

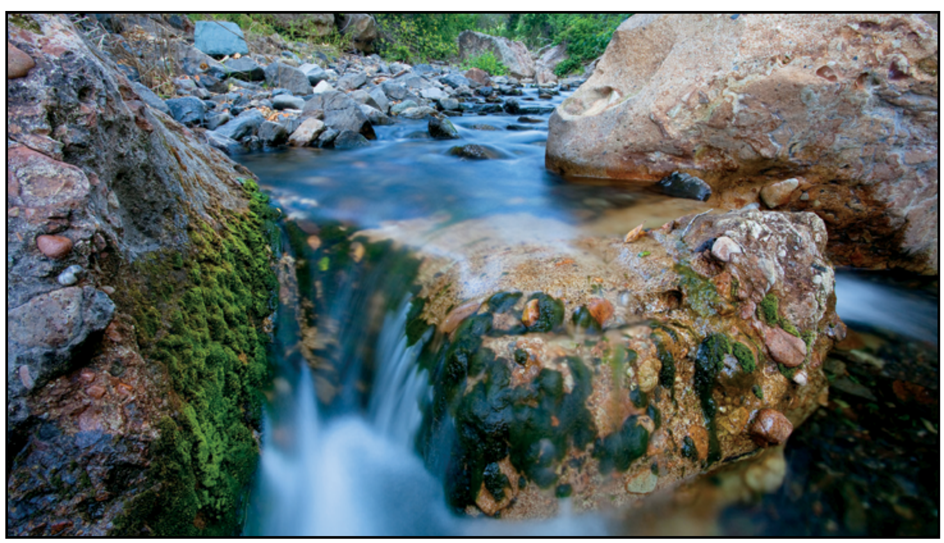
"If you don't know what you expect to find at a site, then any observations you collect will be difficult to interpret," said Dr. Eric Stein, head of SCCWRP's Biology Department. "We need to have appropriate sites to use as a reference to judge our data against."

In highly urbanized environments like in Southern California, however, it's often difficult to find environmentally similar streams not impacted by human activity to serve as appropriate reference points.

Thus, SCCWRP and its partners have focused their efforts in recent years on building sophisticated statistical predictive models to more precisely pinpoint what numbers and types of organisms that environmental managers should expect to find in streams in different environmental settings.

The culmination of this work has been the creation of the California Stream Condition Index, a statewide scoring tool with the capacity to measure the ecological health of nearly any stream site in California – and to generate stream condition scores that are comparable across the state.

The California Stream Condition Index, released in 2015, was



Human activities have impacted the ecological health of California's thousands of miles of streams. To monitor stream health, SCCWRP and its collaborators have developed an environmental scoring tool called the California Stream Condition Index.

co-developed by SCCWRP and the California Department of Fish and Wildlife's Aquatic Bioassessment Lab in partnership with the State Water Board's Surface Water Ambient Monitoring Program, as well as the U.S. Geological Survey, Utah State University, Sierra Nevada Aquatic Research Lab, and U.S. Environmental Protection Agency.

The California Stream Condition Index can account for a continental-scale level of environmental diversity, from the temperate rainforests of coastal Northern California to the chaparral and oak woodlands of Southern California.

"With the CSCI, you input data on environmental factors like elevation, geology, and climate – and then use the tool's models to predict which species you expect to find at a stream site under unimpacted conditions," said Phil Markle, an environmental scientist in the monitoring section of the Sanitation Districts of Los Angeles County. "It blows everything that preceded it out of the water. We can't rave enough about it."

Biological data as reliable measures of stream health

Measuring the numbers and types of insects and other aquatic invertebrates in a stream is not a new concept. Since the early 1900s, scientists have recognized that of the thousands of varieties of small insects and other aquatic organisms dwelling along the bottom of streams, certain species serve as particularly reliable indicators of stream health.

In places like Southern California, however, the stream management community has historically relied on chemistry- and toxicology-based methods to gain insights into stream health. These methods have proven to be simple and dependable for diagnosing a wide variety of human-triggered impacts to the environment.

However, the state's environmental managers have begun to recognize the inherent limitations of these chemistry and toxicology approaches.

First, these methods are often chemical-specific, meaning that each test can only confirm the presence of

The upper portions of Trabuco Creek in the Santa Ana Mountains are minimally impacted by human activities. High-elevation sites like this one may not be appropriate reference sites for streams at lower elevations, as the upper-elevation sites may support more diverse biological communities under natural conditions.

Aquatic invertebrates like the larval dragonfly, above, are sensitive to human-induced changes in water chemistry and habitat. The relative abundance of different species of aquatic invertebrates is used to calculate scores for the California Stream Condition Index.

one pollutant or class of pollutants. For example, if a stream manager doesn't test for the presence of metals in the water, then toxic levels of copper might be missed. Also, it can become prohibitively expensive to test every stream site for every possible contaminant, especially as new pesticides and other synthetic chemicals are introduced to the market.

Second, chemistry and toxicology tests can only reveal the identity of pollutants that are in the water at the moment of sampling. In other words, if a pollutant dissipates prior to sample collection, the presence of a contaminant could go undetected.

By contrast, biological assessments reflect the overall condition of aquatic ecosystems, integrating all of the impacts to which organisms are exposed over their lifetimes. Consequently, even if an organism were exposed to a one-time contaminant release that quickly washes away, the biological data would reflect it, while chemistry tests may not.

"At the end of the day, biological assessment data are preferable because biology is more directly related to the outcomes that we as a society care about – ensuring streams can support robust aquatic life," Stein said.

Accounting for natural variability among streams

A healthy, low-elevation Southern California stream might only support about a dozen species of aquatic insects, while a stream in the mountains of the Sierra Nevada might support several dozen species. To account for these differences, the California Stream Condition Index calculates a different set of reference expectations for each stream. Because the index draws from such a large and diverse set of reference site data, the scoring tool can be used in nearly all of California's wadeable streams.

Scoring based on locally relevant environmental conditions

A major challenge to conducting biology-based stream assessments in Southern California has historically been a dearth of stream reference sites. The biological data from these reference sites serve as points of comparison for tracking biological degradation in streams impacted by human activity.

Traditionally, environmental managers have used sites in undeveloped mountainous regions as their reference sites, as these were often the least impacted sites within highly urbanized watersheds.

But even without any human influence, the numbers and types of aquatic organisms found in low-lying coastal California streams – where ecological assessments of streams are often needed – bear little resemblance to the stream biology of mountainous wilderness regions.

"It was hard to tell if the differences in stream scores we were getting between an urbanized site and its reference sites were meaningful, or if the differences were just caused by natural factors," said Dr. Raphael Mazor, a SCCWRP biologist.

To solve this problem, the California Department of Fish and Wildlife's Aquatic Bioassessment Lab initially worked with partners to build scoring tools custom-designed for specific regions of the state. For example, scientists built separate index scoring tools for California's South Coast region, the Sierra Nevada, and the North Coast.

The region-specific focus of these scoring tools helped reduce the background noise from natural environmental conditions, such as climate, elevation and topography.

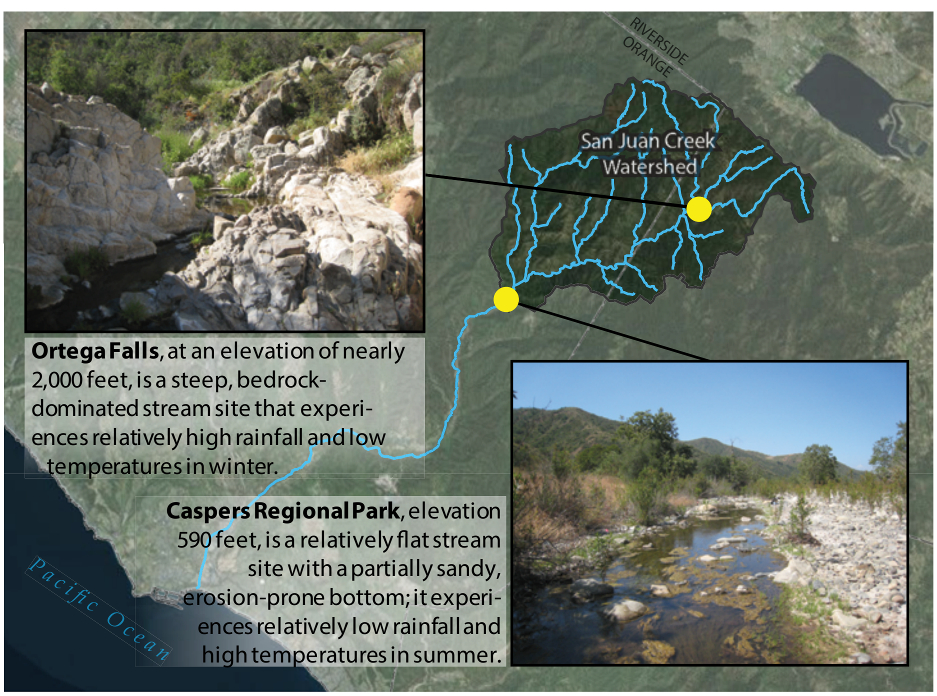
But these regional tools did not completely eliminate the background noise, and they came with problems of their own.

"Because we created these scoring tools to work in specific regions, they wouldn't translate over to a new region very well," said Dr. Peter Ode, director of the California Department of Fish and Wildlife's Water Pollution Control Laboratory, of which the Aquatic Bioassessment Lab is a part.

"We ended up with a patchy collection of these scoring tools that couldn't be compared directly to one another because they were developed independently."

Environmental variability

Different sites along a single watershed, such as the San Juan Creek watershed that spans Riverside and Orange counties, can be subjected to vastly different environmental conditions, including variations in average rain patterns, elevation, and geology. The California Stream Condition Index weighs all of these site-specific environmental factors in determining whether a stream site's aquatic invertebrate community has been impacted by human activity.



Ortega Falls, at an elevation of nearly 2,000 feet, is a steep, bedrock-dominated stream site that experiences relatively high rainfall and low temperatures in winter.

Caspers Regional Park, elevation 590 feet, is a relatively flat stream site with a partially sandy, erosion-prone bottom; it experiences relatively low rainfall and high temperatures in summer.

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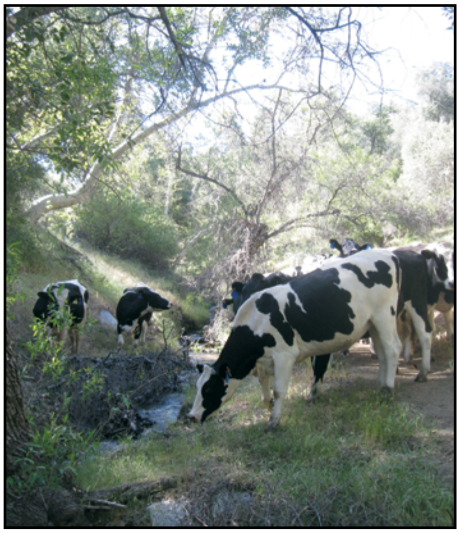


Livestock grazing near streams is one of many human-influenced activities that can degrade the ecological health of streams. Certain aquatic invertebrates are particularly suspectible to these impacts, making them valuable sentinels of stream health.

Integrating lessons learned into a unified, statewide scoring tool

In 2010, a coalition of stream ecologists and managers from across the state came together to begin conceptualizing a single scoring tool that could address these challenges.

The scientific breakthrough came when the team assembled a comprehensive statewide network of California stream reference sites that was both large and diverse enough to build models that could predict biological expectations for nearly any stream site statewide.

The team leveraged data from numerous partners – including the Surface Water Ambient Monitoring Program, Southern California Stormwater Monitoring Coalition, and U.S. Forest Service – to build a network encompassing 590 reference sites that span a broad range of natural environmental settings in California. The network includes settings that had been poorly represented in previous index development efforts, such as the Sierra Nevada foothills and low-gradient streams in Southern California.

The California Stream Condition Index uses this robust reference data set and powerful computer modeling capabilities to explain what the biology at a specific site should look like, given its environmental setting.

While earlier indices occasionally conflated natural factors with human impacts, the chances of such an error have been dramatically reduced with the California Stream Condition Index. Moreover, the California Stream Condition Index has allowed all stream sites across California to be put onto the same scale for the first time.

"With prior scoring tools, a score of 0.75 at one stream site might not mean the same thing as a score of 0.75 at another site," Mazor said. "With the CSCI, we know they do."

In late 2015, the State Water Board's Surface Water Ambient Monitoring Program (SWAMP) published detailed technical manuals and guidance documents that explain how to calculate California Stream Condition Index scores. SWAMP also plotted stream scores from across the state on an interactive, publicly accessible online map.

Since the debut of the California Stream Condition Index, SCCWRP has been working with its partners to offer training across the state, ensuring stream managers become fully proficient in using the tool prior to the State Water Board's planned adoption of a stream biointegrity policy in the next few years. This biointegrity policy will allow the state to create standards governing the ecological health of all California streams.

Eventually, regulatory agencies are interested in using the California Stream Condition Index as an enforcement mechanism for extending new protections to streams. Doing so will require setting regulatory thresholds for stream health that are informed by SCCWRP-developed science, but that are ultimately public

Scoring the health of California streams

The California Stream Condition Index generates a single numerical score for each stream site on a linear scale. A high score means that the site has most of the numbers and types of organisms expected to be found there, and therefore is less likely to be impacted by human activity.

Caballero Creek, a channelized, algae-filled tributary of the Los Angeles River, reflects severe ecological degradation due to human activity. Such streams tend to score low in the California Stream Condition Index. However, scientists are working to determine what range of scores that streams like this can achieve.

Calculating the California Stream Condition Index

The California Stream Condition Index is made up of two components that are averaged together to get a final score.

Observed-to-expected (O/E) ratio

Observed

÷

Expected

Where

Expected = Number of species expected to be present at a site with high probability, given its environmental setting

Observed = Number of those species actually observed at the site

➕

Multi-metric index

Average of six individual measures of the biological diversity found at a stream site

Taxonomic richness: Total number of different species of aquatic insects and other invertebrates found at site

Shredder taxa: Number of species that feed on coarse leaf material

% intolerant taxa: Portion of species that are considered pollution-intolerant because of sensitivity to sewage and other organic pollution

% Ephemeroptera, Plecoptera, and Trichoptera taxa: Portion of species that are classified as either mayflies, stoneflies or caddisflies, all of which are particularly sensitive to human-induced changes in water chemistry

% Coleoptera taxa: Portion of species classified as beetles

% clinger taxa: Portion of species that cling to hard surfaces

Average

Final score

policy decisions.

"As a general monitoring tool, the CSCI is great, but as it moves into the regulatory realm, the state is going to say, 'We want your CSCI score to be X, and if it's not, you're going to have to take specific actions,'" Markle with the Sanitation Districts of Los Angeles County said.

"We're very concerned because we don't know where those thresholds are going to be set – nor do we know how much uncertainty is going to be associated with them."

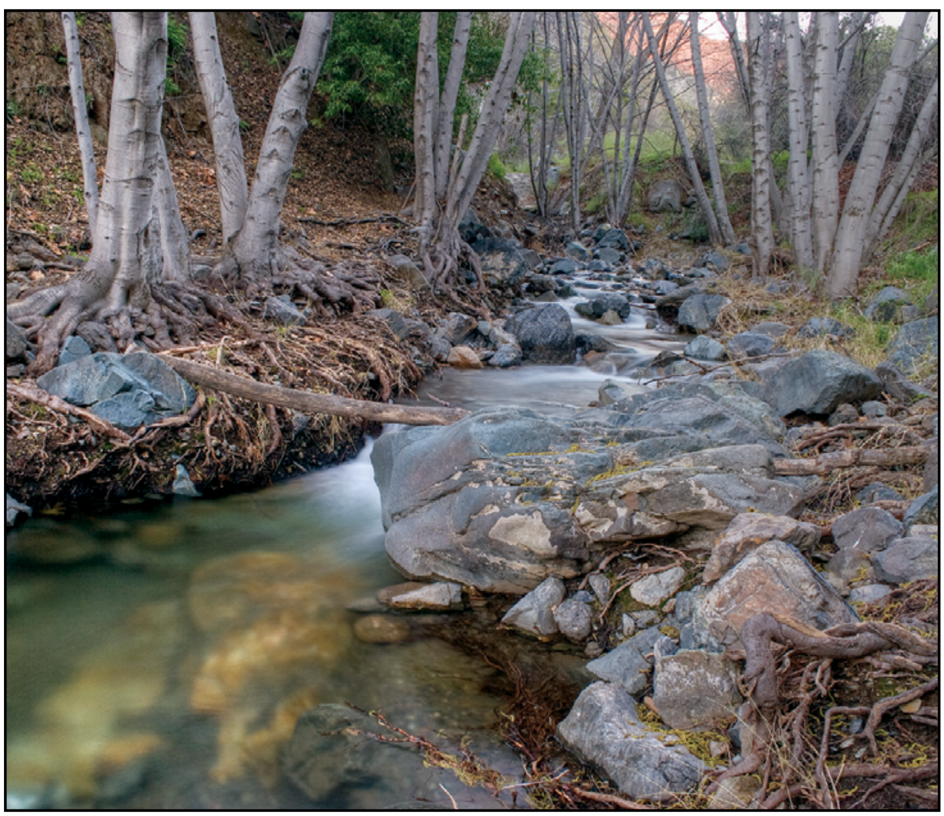
SCCWRP already is working to address these concerns, partnering with collaborators to investigate variability in the index, identify appropriate biological targets for channels that have been modified by human activity, and study the effect of natural variations in water chemistry on index scores.

By giving stream managers a far more precise scoring tool to use for judging the success of their ongoing management programs, SCCWRP and its partners envision the California Stream Condition Index having potential applications in a wide variety of contexts, including setting conservation priorities, evaluating restoration projects, assessing permit compliance, and evaluating the effectiveness of mitigation projects.

"Ultimately, we see the California Stream Condition Index changing the way stream managers do business," Mazor said. "We look forward to helping them realize these opportunities."

Automating index calculations

SCCWRP is working with the California Department of Fish and Wildlife's Aquatic Bioassessment Lab and the State Water Board to develop an automated, web-accessible platform that California stream managers can use to calculate their California Stream Condition Index scores. This calculator will reduce reliance on complex software, including geographic information systems and a statistical programming language known as R, that requires substantial training to use. The California Stream Condition Index Calculator is scheduled to be released in late 2016.



Reference streams like the upper reaches of Bell Canyon in Ventura County allow scientists to set benchmarks for all sorts of environmental measurements, including biological composition, nutrient concentrations, and physical habitat parameters.

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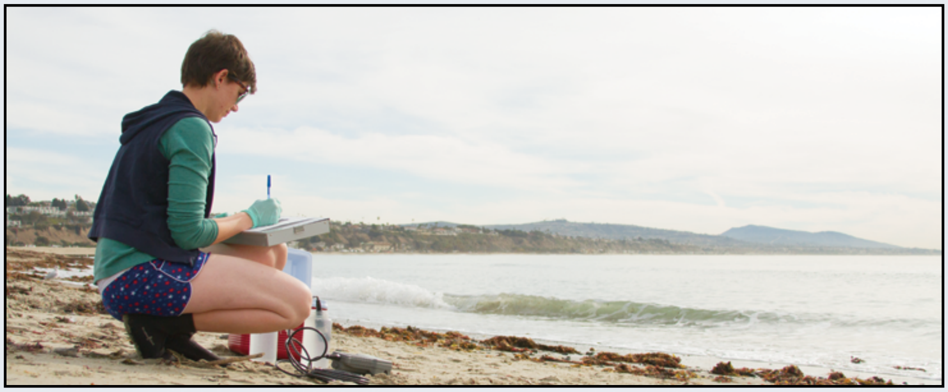
BETTER, FASTER, CHEAPER



New molecular technologies improve detection of microbial contamination in Southern California's coastal waters

Southern California vigorously monitors its coastal waters for dangerously high levels of microbial contamination. During the popular beach-going season, public health officials test water quality at least weekly, and some municipalities test almost daily.

In the rare times that contamination levels are too high, public health officials post warning signs at beaches urging beachgoers not to enter the water.

The reason is simple: Spikes in microbial

contamination – from sources such as sewage spills and leaking sanitation infrastructure – can lead to gastrointestinal illnesses, or cause infections like Staphylococcus when swimmers enter the water with open cuts and wounds.

Although Southern California's coastal water-quality monitoring system is arguably the most robust and comprehensive in the nation, the laboratory testing methods being used to detect microbial contamination are based on approaches that are decades old.

And that is where scientists have an opportunity to make a radical difference.

New molecular microbiology technologies that harness the power of DNA have ushered in a new era for detecting microbial contamination, one that can more reliably and cost-effectively alert public health officials to the presence of waterborne pathogens.

These better, faster, cheaper diagnostic approaches are reducing the time required to test water samples from 24 hours or more to a mere two hours, allowing public health officials to close beaches and warn beachgoers of waterborne threats with unprecedented speed.

DNA-based approaches also are enabling water-quality managers to more effectively pinpoint sources of coastal contamination and determine the health risks associated with coming into contact with waterborne microbes.

"We're on the cusp of making beach water-quality monitoring better than it's ever been," said Dr. John Griffith, an aquatic microbiologist who heads SCCWRP's Microbiology Department. "With newer technologies, we won't need an entire day to detect microbial contaminants in beach water; we'll have an answer in two hours."

In recent years, the groundbreaking beach water-quality testing protocols pioneered by scientists, including at SCCWRP, have been transferred into use by public health and environmental monitoring agencies across Southern California and beyond.

Rain water pours out of a storm drain that terminates at the beach. This water carries land-based pollution to the coastal zone, where it can pose a health risk to beachgoers.

Laboratories have installed cutting-edge molecular microbiology facilities based on SCCWRP recommendations, invested in hundreds of thousands of dollars' worth of next-generation microbiology equipment, and begun to push proactively for additional research and changes to regulatory policy to help them more fully reap the benefits of this technology.

"We want to catch up with technology because the sooner we can get results to the public, the better off they'll be protected," said Laila Othman, microbiology lab supervisor for the City of San Diego Public Utilities Department's environmental protection division. "Having SCCWRP has helped us get so much more use out of our technology; we wouldn't be where we are today without SCCWRP."

Sonji Romero, left, and Zaira Valdez from the City of San Diego's marine microbiology lab practice using a quantitative PCR machine to test water samples for microbial contamination during a SCCWRP-led training and intercalibration exercise in 2013.

Molecular technologies represent major step forward

Advances in molecular microbiology over the past three decades have made possible the beach monitoring technologies being developed by SCCWRP and its partners.

Jessica Roussos, left, and Dr. Samuel Choi of the Orange County Sanitation District's Environmental Laboratory and Ocean Monitoring Division prepare to analyze water samples for microbial contamination using their lab's quantitative PCR machine. Science conducted by SCCWRP and its collaborators has demonstrated why public-health and environmental-monitoring laboratories should invest in qPCR technology.

Incremental advance with IDEXX method

Prior to plowing full speed ahead into molecular methods, scientists did their best to achieve greater efficiencies with culture-based methods. In the late 1990s, SCCWRP and its collaborators rolled out a more efficient, less labor-intensive protocol for water-quality monitoring using a commercially available technology for quantifying microbes called IDEXX, originally developed for diagnostic medical, food-safety, and drinking-water testing. Although the IDEXX method – named after the manufacturer of the equipment – represented an improvement over older methods, it was still a growth-based method that was limited by the time required for bacteria to grow. The IDEXX method is still widely used today, but is gradually giving way to molecular-based approaches.

With molecular microbiology, scientists are able to isolate and study very specific segments of DNA from waterborne bacteria, viruses and other pathogens in beach water – and ultimately to identify and quantify specific microbes of interest.

SCCWRP and its collaborators have zeroed in on these molecular technologies – typically developed first for diagnostic medical and pharmaceutical applications – and figured out how to adapt them for beach water-quality testing.

Molecular microbiology methods represent a monumental step forward in Southern California's efforts to better protect its beachgoers, as they have the potential to replace the decades-old culture-based techniques that have been a stalwart of beach water-quality monitoring.

While newer molecular methods focus on the genetic material of waterborne microbes, traditional growth-based techniques involve filtering microbes out of a water sample and allowing the microbes to grow in tubes of growth broth or on agar plates. The microbes must be subjected to a lengthy incubation period, typically 18 to 72 hours, before a lab technician can ascertain what grows.

By the time a lab completes all of these steps and analyzes the results, more than 24 hours has typically passed. Consequently, by the time that public health officials confirm a beach is polluted by unsafe levels of microbial contamination, an entire day's worth of beachgoers could have been exposed to waterborne pathogens.

Activism to improve beach water quality

The push for more rigorous water-quality testing at Southern California's beaches can be traced back to the birth of the modern environmental movement in the late 1960s. As environmental regulators and activists learned about the damaging effects of discharging raw and lightly treated sewage into coastal marine environments, and as outraged citizens became increasingly frustrated they might be swimming in dangerously polluted waters, pressure on local officials mounted. Over the next three decades, from the 1970s to the 1990s, aging sanitation infrastructure was significantly expanded and modernized, the practice of discharging lightly treated sludge solids into coastal waters was abandoned, and standardized notification systems were put in place to warn beachgoers within minutes of raw sewage spills. In light of this progress, coastal water-quality managers have now turned much of their attention to solving the biggest remaining challenge: Reducing the sources of land-based contamination that travel through miles of rivers, creeks and storm drain systems to the coastal zone.

Furthermore, if the elevated levels of microbial contamination dissipate by the time the first warning signs are posted at a beach, then the warnings become useless.

"The problem with culture methods is that it just takes too long to get results," said Dr. Joshua Steele, an aquatic microbiologist at SCCWRP. "This is an inherent limitation of traditional methods – there's no way to get around all of that processing and incubation time."

Unlocking the power of qPCR

In the early 2000s, a coalition of universities and other agencies began to systematically evaluate promising molecular methods and lay a scientific foundation to adapt molecular technologies for use in the highly regulated world of beach water-quality monitoring.

Ultimately, the scientists, including at SCCWRP, developed consensus around a molecular method known as the quantitative polymerase chain reaction (qPCR), in which a fluorescent genetic marker is used to quantify the presence of certain types of DNA in a given water sample. This DNA comes from bacteria that are commonly found in high concentrations when human sewage or other fecal material is present.

The research demonstrated that at most beaches, quantifying the indicator bacteria using qPCR is just as reliable as culture-based methods, with results that can be generated within a few hours instead of a day or more.

And the qPCR method has another important advantage: It also can be used to identify whether humans or other animal species are responsible for observed aquatic contamination.

Known as microbial source tracking, this approach is an incredibly powerful asset for beach water-quality managers, as it can determine whether microbial contamination is coming from a specific animal, such as a horse or a bird, or from a human source. Aquatic contamination from human sources, such as leaking sewer infrastructure, is far more likely to contain microbes dangerous to humans than water contaminated by the feces of a dog or seagull or most other animals.

Furthermore, when multiple sources of microbial contamination are identified, qPCR can help scientists determine which portions came from which sources.

"This is information that culture-based methods simply can't tell us," said Dr. Yiping Cao, an aquatic microbiologist at SCCWRP. "These data are incredibly valuable for managers as they try to trace where contamination at the beach is coming from."

When microbial contamination in coastal waters reaches levels deemed unsafe, public health officials post warning signs at beaches advising beachgoers to stay out.

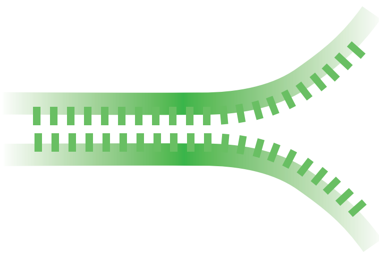
Transitioning qPCR to water-quality managers

In recent years, SCCWRP and its collaborators have been working to perfect qPCR-based technologies and to demonstrate their performance for

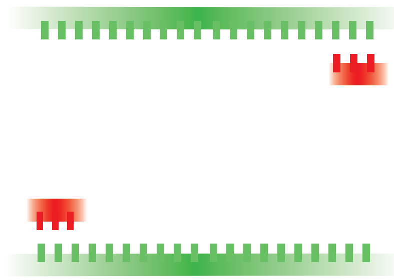
Southern California's world-famous beaches benefit from regular monitoring for microbial contamination during the warmer parts of the year. Scientific advances are paving the way for microbial contamination to be detected faster and more reliably than ever before.

Using qPCR to quantify microbial contamination

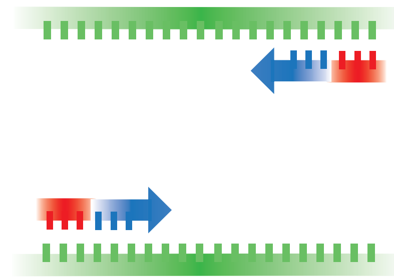
qPCR is a next-generation approach to the polymerase chain reaction that uses a fluorescent marker to quantify the amount of DNA present in a sample. With qPCR, public health officials can efficiently and accurately measure levels of microbial contamination in beach water.



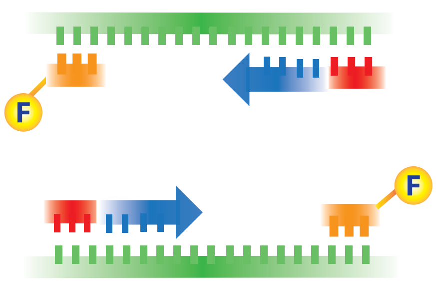
1 DNA from water sample contaminated with microbes is denatured into two strands via heating.



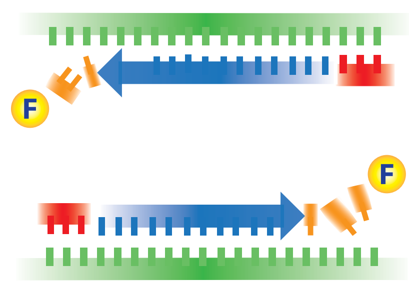
2 RNA primers bind to the DNA of the microbial contaminant.



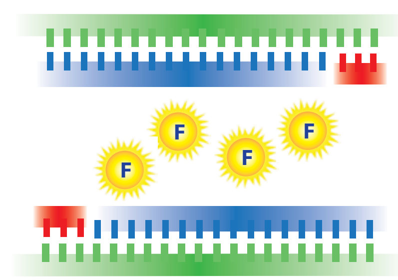
3 DNA replication, known as polymerization, begins.



4 Probes attached to a fluorescent marker bind to a specific spot on the DNA.



5 As polymerization reaches the probe, the probe is degraded, which releases and activates the fluorescent marker.



6 As the target DNA continues to be amplified, a high-energy light source excites the fluorescent marker, and the amount of fluorescent signal is measured.

regulatory applications. In 2012, the U.S. Environmental Protection Agency approved qPCR-based water-quality monitoring for general use across the nation.

SCCWRP's role now is to help environmental monitoring and public health laboratories to make the transition to qPCR-based methodologies – and to help these labs phase out their use of culture-based methods.

In 2013, 14 laboratories in coastal municipalities spanning from San Francisco to San Diego signed up to participate in a SCCWRP-led training exercise and quality-control study intended to expand the labs' ability to use qPCR for environmental monitoring.

Setting up a laboratory to do qPCR is not an inexpensive proposition; it can cost upward of $100,000 to outfit a lab.

Meanwhile, for the 2013 cycle of the Southern California Bight Regional Monitoring Program, SCCWRP helped dozens of laboratories to develop capacity to run qPCR, as well as facilitated an intercalibration study designed to ensure high-quality, comparable results across the Southern California Bight.

And SCCWRP continues to receive questions and requests for help setting up qPCR for environmental monitoring from laboratories as far away as New York and Rhode Island.

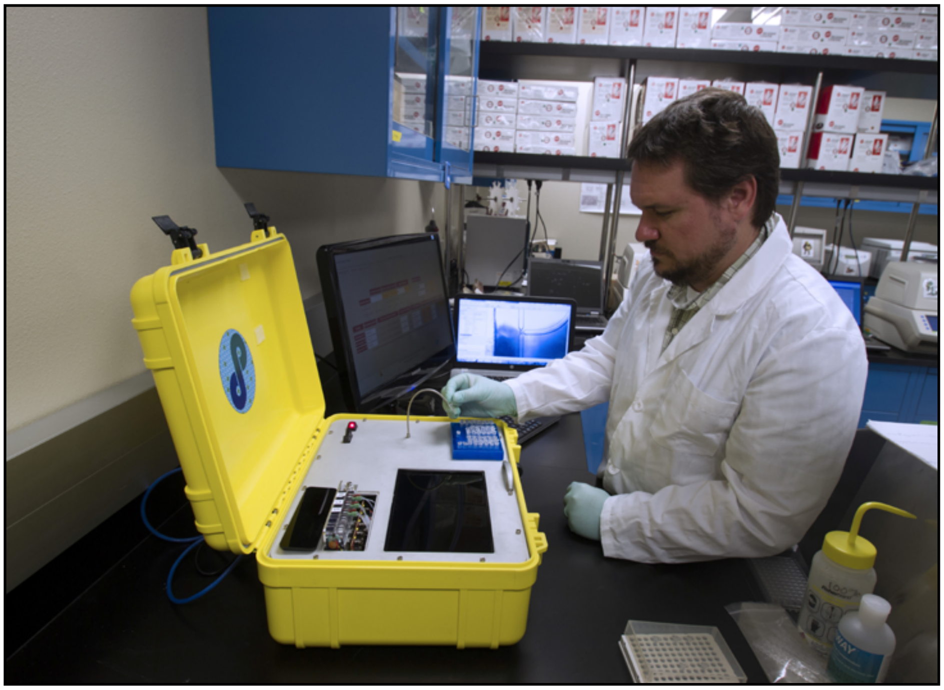
"When it comes to developing faster, cheaper methods and being able to track coastal contamination to the source, there's no one more advanced than SCCWRP," said Dr. Mark Gold, associate vice chancellor for environment and sustainability at the University of California, Los Angeles, and the former long-time head of the Santa Monica-based coastal environmental group Heal the Bay. "These advances have been absolutely critical to protecting public health."

Limitation of DNA-based monitoring

DNA-based microbial detection methods can accurately quantify contamination levels most of the time, but one notable exception is when water has recently been disinfected, as happens during wastewater treatment. The problem is that the DNA of the microbes does not break down during disinfection, even though the microbes themselves are rendered harmless. Thus, DNA-based microbial detection methods can overstate contamination levels. Scientists are working on methods that can differentiate between DNA from live vs. dead microbes.

Making qPCR technology even faster

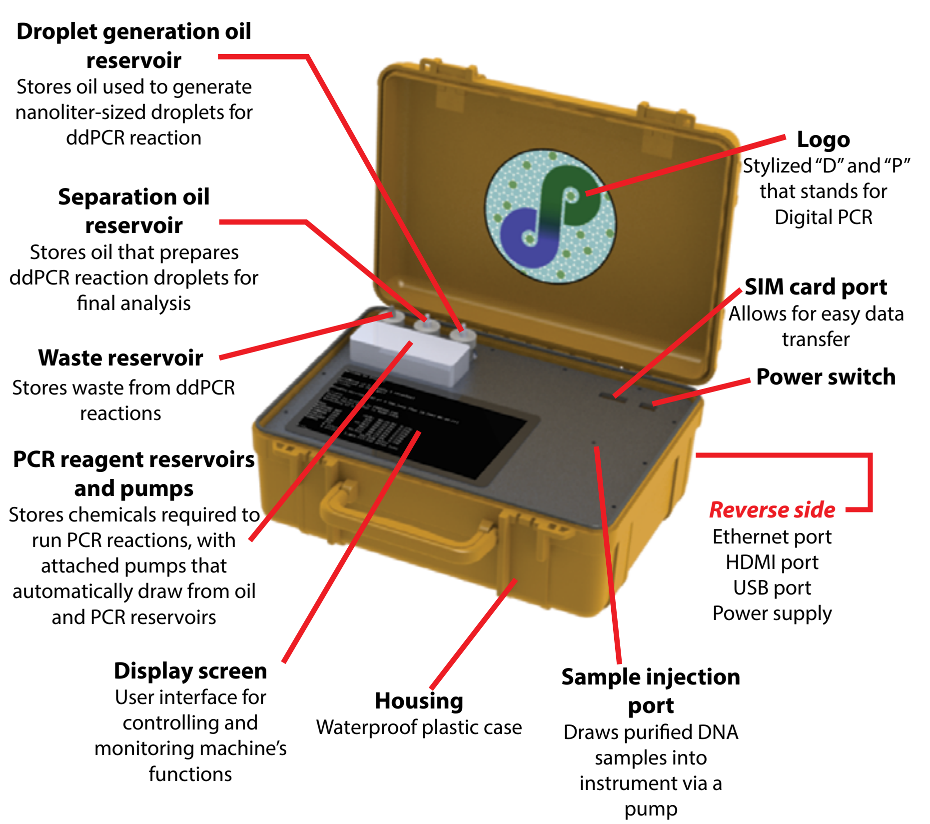
With standard qPCR technology, a qPCR machine sits on a benchtop in



SCCWRP's Dr. Joshua Steele calibrates a briefcase-sized prototype instrument that uses qPCR to detect aquatic microbial contamination. The device could revolutionize the speed at which water-quality managers can measure and track sources of waterborne contaminants.

Portable qPCR machine prototype

Researchers at Arizona State University are working to refine the design of a portable qPCR machine that uses droplet digital PCR (ddPCR) technology to test water samples for microbial contamination. The design will continue to evolve as the instrument moves toward commercial production.



a centrally located laboratory. In other words, field samplers spend critical time transporting the samples they've collected at the beach to a lab for analysis.

SCCWRP is working to change that paradigm – and to enable qPCR technology to deliver results even faster.

In collaboration with an Arizona State University physics lab and the Monterey Bay Aquarium Research Institute, SCCWRP is seeking to shrink the fragile, 30-pound qPCR machine down to the size of a briefcase. The fully mobile, field-deployable device will then be able to accompany water-quality testers to the beach and other aquatic environments.

In 2015, a prototype of the field-deployable, portable qPCR machine was unveiled at SCCWRP. The prototype device is able to accept purified DNA from a water sample about once every five minutes, with results available about two hours after a sample is fed into the machine.

The qPCR device, which uses an even more advanced type of qPCR known as droplet digital PCR, also is in the process of being coupled with an automated sample preparation device that will make it possible to feed raw, unprocessed water samples into a machine and obtain results at the other end.

This end-to-end solution can then be repackaged to fit into the nosecone of an autonomous underwater vehicle, enabling it to automatically analyze water samples in real time in the open ocean.

Meanwhile, the Arizona State University physics lab that built the field-portable prototype is forming a private company that will work on redesigning the prototype instrument so it can be sold on the commercial market. The device could be ready for sale in as little as three or four years.

"This is going to be an instrument that is so simple to use that a beach lifeguard could be trained to operate it," Griffith said. "We're talking about a technological advancement that has the potential to once again revolutionize the field of water-quality testing."

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Accomplishments

The feature articles in this Annual Report chronicling how SCCWRP science has been adopted by the end-user water-quality management community are just four examples of SCCWRP's scientific accomplishments. The agency works across nine major thematic research areas. What follows is an overview of key milestones and accomplishments within each of these areas for 2015. The write-ups for each research area are accompanied by abstracts for all peer-reviewed journal articles from 2015 that relate to the research area, as well as citations for technical reports. In all, 56 articles and reports co-authored by SCCWRP scientists are featured.

SCCWRP Research Areas

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 gauge the health of streams, wetlands and 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.

Contaminants of Emerging Concern
To prioritize tens of thousands of inadequately studied and largely unmonitored contaminants of emerging concern (CECs) in water bodies for screening and risk assessment, SCCWRP is developing novel approaches to more widely and effectively 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.

Eutrophication
With anthropogenic nutrient inputs a leading cause of eutrophication – or accelerated accumulation of organic matter from overgrowth of aquatic plants and algae – SCCWRP is working to help environmental managers understand the deleterious impacts of excessive nutrients in both freshwater and marine coastal waters by diagnosing eutrophication, identifying appropriate nutrient targets for water bodies, and tracking where nutrients are coming from and how they biogeochemically interact with aquatic ecosystems.

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 and effectively detect beach microbial contamination and characterize the risks of water-contact illness for humans. SCCWRP also is working to advance the science used to identify source(s) of contamination and quantify the degree to which human health is adversely impacted by them.

Ecohydrology
As humans change hydrological flow patterns over time, the physical structure of water bodies can be altered, triggering impacts to the biological communities that reside in and around them. SCCWRP is working to understand the relationship between these hydrological/physical alterations and the resulting impacts to biological health, a field known as ecohydrology.

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 to assess their condition, functioning, 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. SCCWRP's signature, cyclical programs are the Southern California Bight Regional Monitoring Program for marine ecosystems and its freshwater counterpart, the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program.

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.

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 in 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 and that 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, and that can 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; and (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.

In 2015, SCCWRP developed new scoring tools for highly episodic streams that have previously been excluded from routine assessment programs because of existing tools were not applicable. SCCWRP also facilitated implementation of recently completed bioassessment scoring and causal assessment tools by developing user manuals, conducting technology transfer, developing training courses, and assisting local and state stakeholder groups in tool application. Accomplishments in 2015 include:

» **Developing a new assessment tool for dryland and highly episodic streams:** SCCWRP has released a new module of the California Rapid Assessment Method (CRAM) to help stream managers conduct bioassessments in dryland, or highly episodic, streams. Dryland streams are found in arid climates and in the upper portions of watersheds, and typically flow only sporadically, for hours to days following extreme rain events, or not at all in some years. Traditional bioassessment tools do not work in this stream type because traditional in-stream biological communities do not have time to become established. These streams, however, are prolific in California, comprising more than half of all stream miles in some watersheds, and up to 90% of stream miles in especially dry regions. The new CRAM module is designed to assess stream condition by examining the physical structure, plant community composition, and buffer properties of the stream flow zone. The episodic CRAM module, released in 2015, is the culmination of more than three years of development and testing across California; it also includes a decision tree to help users determine when to use the new module at a given site. The episodic CRAM module has been incorporated in the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program, expanding the breadth of streams that can be included in this ongoing regional stream survey.

» **Implementing a new statewide stream bioassessment scoring tool:** SCCWRP and its partners have unveiled a new macroinvertebrate scoring tool for streams that can be consistently applied throughout California. The California Stream Condition Index, released in 2015, represents an important advancement in stream monitoring, allowing managers to generate condition scores using site-specific biological expectations that account for the stream's unique environmental characteristics. SCCWRP facilitated application of the CSCI in several statewide assessment and management programs in 2015, including the California Perennial Stream Assessment, in which SCCWRP helped apply the CSCI to more than 1,400 sampling sites covering 13 years of monitoring data (2000-12). The analysis found that 44% of stream miles were in good biological condition, 34% were in degraded (i.e., poor or very poor) condition, and 22% were in fair condition. SCCWRP also worked with the state's Surface Water Ambient Monitoring Program (SWAMP) to publish a CSCI technical memo and accompanying instruction manual and fact sheet that explain how to calculate index scores, and to co-host workshops to train staff at regional boards, who, in turn, will train end users within their regions. Two peer-reviewed articles about the development of the CSCI have also been published as open-source journal articles in *Freshwater Science*. SCCWRP also helped SWAMP build an interactive map to make CSCI scores publicly accessible for nearly 2,000 streams statewide.

» **Advancing the application of causal assessment:** SCCWRP has developed a set of advanced tools for application of causal assessment in multiple watersheds, enabling SCCWRP to develop local capacity for implementation in partnership with local stakeholders. SCCWRP helped conduct a multi-site, stream reach-scale approach to causal assessment in San Diego Creek in Orange County in 2015, which evolved the CADDIS (Causal Analysis/Diagnosis Decision Information System) causal assessment framework beyond its current single-site scale limitations to better deal with chronic nonpoint source stressors found throughout Southern California. During this project, SCCWRP facilitated technology transfer and training for Santa Ana Regional Water Quality Control Board staff and watershed stakeholders in the San Diego Creek watershed, and taught a causal assessment short course in Sacramento. SCCWRP also developed appropriate post-causal assessment actions for the San Diego River Watershed in San Diego County. These actions focus on stressors already identified during the original causal assessment as a likely cause of impairment (synthetic pyrethroid pesticides and elevated conductivity) or as indeterminate (altered physical habitat and elevated nutrients). For example, the new assessment tool for pyrethroids and other potentially toxic chemicals use Toxicity Identification and Evaluation (TIE) data.

Evaluating the adequacy of a reference-site pool for ecological assessments in environmentally complex regions

Peter R. Ode[1], Andrew C. Rehn[1], Raphael D. Mazor[1,2], Kenneth C. Schiff[2], Eric D. Stein[2], Jason T. May[3], Larry R. Brown[3], David B. Herbst[4], David Gillett[2], Kevin Lunde[5], Charles P. Hawkins[6]

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[2]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[3]*US Geological Survey, Sacramento, CA*
[4]*Sierra Nevada Aquatic Research Laboratory, Mammoth Lakes, CA*
[5]*San Francisco Bay Regional Water Quality Control Board, Oakland, CA*
[6]*Western Center for Monitoring and Assessment of Freshwater Ecosystems, Department of Watershed Sciences, and the Ecology Center, Utah State University, Logan, UT*

Abstract

Many advances in the field of bioassessment have focused on approaches for objectively selecting the pool of reference sites used to establish expectations for healthy waterbodies, but little emphasis has been placed on ways to evaluate the suitability of the reference-site pool for its intended applications (e.g., compliance assessment vs ambient monitoring). These evaluations are critical because an inadequately evaluated reference pool may bias assessments in some settings. We present an approach for evaluating the adequacy of a reference-site pool for supporting biotic-index development in environmentally heterogeneous and pervasively altered regions. We followed common approaches for selecting sites with low levels of anthropogenic stress to screen 1985 candidate stream reaches to create a pool of 590 reference sites for assessing the biological integrity of streams in California, USA. We assessed the resulting pool of reference sites against 2 performance criteria. First, we evaluated how well the reference-site pool represented the range of natural gradients present in the entire population of streams as estimated by sites sampled through probabilistic surveys. Second, we evaluated the degree to which we were successful in rejecting sites influenced by anthropogenic stress by comparing biological metric scores at reference sites with the most vs fewest potential sources of stress. Using this approach, we established a reference-site pool with low levels of human-associated stress and broad coverage of environmental heterogeneity. This approach should be widely applicable and customizable to particular regional or programmatic needs.

Citation
Ode, P.R., A.C. Rehn, R.D. Mazor, K.C. Schiff, E.D. Stein, J.T. May, L.R. Brown, D.B. Herbst, D. Gillett, K. Lunde, C.P. Hawkins. 2015. Evaluating the adequacy of a reference-site pool for ecological assessments in environmentally complex regions. *Freshwater Science* DOI 10.1086/68400.

SCCWRP Journal Article #0886
Full text available by request: pubrequest@sccwrp.org

Bioassessment in complex environments: Designing an index for consistent meaning in different settings

Raphael D. Mazor[1,2], Andrew C. Rehn[2], Peter R. Ode[2], Mark Engeln[1], Kenneth C. Schiff[1], Eric D. Stein[1], David J. Gillett[1], David B. Herbst[3], Charles P. Hawkins[4]

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Abstract
Regions with great natural environmental complexity present a challenge for attaining 2 key properties of an ideal bioassessment index: 1) index scores anchored to a benchmark of biological expectation that is appropriate for the range of natural environmental conditions at each assessment site, and 2) deviation from the reference benchmark measured equivalently in all settings so that a given index score has the same ecological meaning across the entire region of interest. These properties are particularly important for regulatory applications like biological criteria where errors or inconsistency in estimating site-specific reference condition or deviation from it can lead to management actions with significant financial and resource-protection consequences. We developed an index based on benthic macroinvertebrates for California, USA, a region with great environmental heterogeneity. We evaluated index performance (accuracy, precision, responsiveness, and sensitivity) throughout the region to determine if scores provide equivalent ecological meaning in different settings. Consistent performance across environmental settings was improved by 3 key elements of our approach: 1) use of a large reference data set that represents virtually all of the range of natural gradients in the region, 2) development of predictive models that account for the effects of natural gradients on biological assemblages, and 3) combination of 2 indices of biological condition (a ratio of observed-to-expected taxa [O/E] and a predictive multimetric index [pMMI]) into a single index (the California Stream Condition Index [CSCI]). Evaluation of index performance across broad environmental gradients provides essential information when assessing the suitability of the index for regulatory applications in diverse regions.

Citation
Mazor, R.D., A.C. Rehn, P.R. Ode, M. Engeln, K.C. Schiff, E.D. Stein, D.J. Gillett, D.B. Herbst, C.P. Hawkins. 2015. Bioassessment in complex environments: designing an index for consistent meaning in different settings. *Freshwater Science* doi: 10.1086/684130.

SCCWRP Journal Article #0889
Full text available by request: pubrequest@sccwrp.org

Correspondence of biological condition models of California streams at statewide and regional scales

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Abstract
We used boosted regression trees (BRT) to model stream biological condition as measured by benthic macroinvertebrate taxonomic completeness, the ratio of observed to expected (O/E) taxa. Models were developed with and without exclusion of rare taxa at a site. BRT models are robust, requiring few assumption compared with traditional modeling techniques such as multiple linear regression. The BRT models were constructed to provide baseline support to stressor delineation by identifying natural physiographic and human land use gradients affecting stream biological condition statewide and for eight ecological regions within the state, as part of the development of numerical biological objectives for California's wadeable streams. Regions were defined on the basis of ecological, hydrologic, and jurisdictional factors and roughly corresponded with ecoregions. Physiographic and land use variables were derived from geographic information system coverages. The model for the entire state (n=1,386) identified a composite measure of anthropogenic disturbance (the sum of urban, agricultural, and unmanaged roadside vegetation land cover) within the local watershed as the most important variable, explaining 56% of the variance in O/E values. Models for individual regions explained between 51% and 84% of the variance in O/E values. Measures of human disturbance were important in the three coastal regions. In the South Coast and Coastal Chaparral, local watershed measures of urbanization were the most important variables related to biological condition, while in the North Coast the composite measure of human disturbance at the watershed scale was most important. In the two mountain regions natural gradients were most important, including slope, precipitation, and temperature. The remaining three regions had relatively small sample sizes (n≤75 sites) and had models that gave mixed results. Understanding the spatial scale at which land use and land cover affect taxonomic completeness is imperative for sound management. Our results suggest that invertebrate taxonomic completeness is affected by human disturbance at the statewide and regional levels, with some differences

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among regions in the importance of natural gradients and types of human disturbance. The construction and application of models similar to the ones presented here could be useful in the planning and prioritization of actions for protection and conservation of biodiversity in California streams.

Citation

May, J.T., L.R. Brown, A.C. Rehn, I.R. Waite, P.R. Ode, R.D. Mazor, K.C. Schiff. 2015. Correspondence of biological condition models of California streams at statewide and regional scales. *Environmental Monitoring and Assessment* 187:4086.

SCCWRP Journal Article #0845
Full text available by request: pubrequest@sccwrp.org

Evaluating ecological states of rocky intertidal communities: A best professional judgment exercise

Steven N. Murray[1], Stephen B. Weisberg[2], Peter T. Raimondi[3], Richard F. Ambrose[4], Christy A. Bell[3], Carol A. Blanchette[5], Jennifer L. Burnaford[1], Megan N. Dethier[6], John M. Engle[5], Michael S. Foster[7], C. Melissa Miner[3], Karina J. Nielsen[8], John S. Pearse[3], Daniel V. Richards[9], Jayson R. Smith[10]

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Abstract

A Best Professional Judgment (BPJ) exercise was performed to determine the level of agreement among experts in evaluating the ecological states of western North American rocky intertidal communities. Species-abundance and environmental data from 12 central and 11 southern California sites were provided to 14 experts who independently ranked communities from best to worst and assigned each to one of five categories based on the degree of deviation from an expected natural biological state. Experts achieved Spearman correlations of 0.49 (central California) and 0.30 (southern California) in their rankings and averaged 75.4% and 70.0% Euclidean Similarity (ES) in their community evaluations. These ES values compare favorably with agreement levels found for similar exercises with soft bottom macroinvertebrate assemblages. The experts emphasized macrophytes with functional characteristics related to morphology and sessile macroinvertebrates in their assessments. Several challenges were noted in interpreting rocky intertidal data sets, the most prominent of which are high spatial and temporal variation and site-to-site differences in natural disturbance regimes, features that lead to multiple, expected community states. Experts required detailed, physical habitat descriptions to develop community composition expectations that differed for different shore types, and expressed concern about evaluating rocky intertidal communities based on only a single sampling event. Distinguishing natural from anthropogenic disturbance without information on the sources and magnitudes of anthropogenic perturbation was also found to be challenging because the biological responses to these stressors are often similar. This study underscores the need for long-term data sets that describe the dynamics of populations and communities and rigorous testing of expert judgments to firmly establish broadly applicable and consistent links between community states and anthropogenic stressors on rocky shores.

Citation

Murray, S.N., S.B. Weisberg, P.T. Raimondi, R.F. Ambrose, C. Bell, C.A. Blanchette, J.L. Burnaford, M.N. Dethier, J.M. Engle, M.S. Foster, C.M. Miner, K.J. Nielsen, J.S. Pearse, D.V. Richards, J.R. Smith. 2016. Evaluating ecological states of rocky intertidal communities: A best professional judgment exercise. *Ecological Indicators* 60:802–814.

SCCWRP Journal Article #0881
Full text available by request: pubrequest@sccwrp.org

The California Stream Condition Index (CSCI): A new statewide biological scoring tool for assessing the health of freshwater streams

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[2]*Southern California Coastal Water Research Project, Costa Mesa, CA*

Citation

Rehn, A.C., R.D. Mazor, P.R. Ode. 2015. The California Stream Condition Index (CSCI): A New Statewide Biological Scoring Tool for Assessing the Health of Freshwater Streams. Technical Report 883. SWAMP-TM-2015-0002. Surface Water Ambient Monitoring Program. Sacramento, CA.

SCCWRP Technical Report #0883
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/883_CSCI-StatewideBioScoringTool.pdf

Causal assessment evaluation and guidance for California

Kenneth Schiff[1], David J. Gillett[1], Andrew Rehn[2], Michael Paul[3]

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[2]*California Department of Fish and Wildlife, Sacramento, CA*
[3]*Tetra Tech, Inc., Pasadena, CA*

Citation

Schiff, K., D.J. Gillett, A. Rehn, M. Paul. 2015. Causal Assessment Evaluation and Guidance for California. Technical Report 750. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0750
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/750_CausalAssessmentGuidance041515wCov.pdf

Standard operating procedures (SOP) for collection of macroinvertebrates, benthic algae, and associated physical habitat data in California depressional wetlands

A. Elizabeth Fetscher[1], Kevin Lunde[2], Eric D. Stein[1], Jeffrey S. Brown[1]

[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[2]*San Francisco Bay Regional Water Quality Control Board, Oakland, CA*

CITATION

Fetscher, A.E., K. Lunde, E.D. Stein, J.S. Brown. 2015. Standard Operating Procedures (SOP) for Collection of Macroinvertebrates, Benthic Algae, and Associated Physical Habitat Data in California Depressional Wetlands. Technical Report 832. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0832
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/832_swamp_wetlands_sopWDataSheets.pdf

Sediment Quality

SCCWRP Accomplishments

The quality of sediment that underlies waterbodies 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 widely applicable sediment quality assessment framework designed to gauge 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 begun developing sophisticated mathematical models that quantify how contamination from sediment moves through food webs and bioaccumulates in seafood consumed by humans and wildlife.

SCCWRP's research on sediment quality falls into the two main categories reflecting the two main routes by which organisms become exposed to sediment contamination: direct exposure, where bottom-dwelling marine life comes into contact with and/or ingests contamination in sediment, and indirect exposure, where predators accumulate toxins in their bodies as they consume contaminated prey. Each exposure route calls for a different conceptual approach to building a comprehensive assessment framework that can accurately measure and estimate the impacts of sediment contamination on the organisms exposed to it. SCCWRP's 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 pursued 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 2015 include:

» **Tracking improvements to sediment quality via Bight '13:** Sediment toxicity testing conducted as part of the Southern California Bight 2013 Regional Monitoring Program has revealed evidence of continuing improvement to sediment quality. Overall, more than 88% of Bight sediments were found to be nontoxic to sediment-dwelling amphipods and mussel embryos, and most of the toxicity detected was of low severity, according to the Bight '13 Sediment Toxicity Report published in 2015. In particular, bays and estuaries – traditionally the locations of greatest impact – showed a continuing trend of toxicity improvement relative to past Bight surveys. The toxicity survey, a collaborative effort among six laboratories, evaluated a total of 232 sediment samples collected from bays, estuaries, and offshore habitats. Included for the first time was a regional evaluation of sediment toxicity in submarine canyons, which found a greater extent of toxicity in the canyons (16% of area) compared to surrounding shelf sediments (<2%). Completion of Bight '13 analyses using two other lines of evidence – sediment chemistry and benthic community – will provide the data needed to help determine the likely cause and significance of the toxicity results, as toxicity results provide just one of the three lines of evidence needed for a confident assessment of sediment quality.

» **Applying the direct-effects SQO compliance framework to L.A./Long Beach Harbor:** SCCWRP in 2015 worked with the Los Angeles/Long Beach Harbor Technical Work Group to set implementation guidance for applying the SCCWRP-developed direct-effects SQO (Sediment Quality Objectives) compliance framework to the harbor waters TMDL (total maximum daily load). The work group developed a draft framework that provides an updated process for assessing TMDL compliance with SQO for benthic community impacts; this framework, which incorporates regional monitoring and stressor identification data, is better aligned with the characteristics of the SQO assessment process. The State Water Board is planning to adapt the framework for use in other programs across the state aimed at helping sediment-quality managers achieve compliance with TMDLs and other regulatory enforcement actions.

» **Tracking changes to fish gene expression patterns in response to pollutant exposure:** SCCWRP in 2015 completed a study examining how a gene expression microarray containing probes for 14,000 genes could be used to measure gene expression patterns of hornyhead turbot that had been exposed to different chemical pollutant mixtures. The proof-of-concept study involved conducting gene expression analyses on livers from hornyhead turbot that had been exposed in the lab to mixtures of one of two chemicals – either the industrial chemical class known as PCBs or the flame retardant chemical class known as PDBEs. The two types of chemicals are common contaminants in sediment and fish. Changes in expression for about 420 genes in the exposed fish were observed. Furthermore, the pattern of changes in gene expression correlated strongly with the type of contaminant the fish had been exposed to, demonstrating the powerful potential of microarrays to help detect and differentiate among the effects of contaminants present in complex environmental mixtures in sediments. Follow-up studies are planned to investigate the linkage between gene expression changes and changes in fish health, and to understand the effects that other factors may have on gene expression changes in wild fish from contaminated sites, including magnitude of chemical exposure, fish size, life stage, and movement patterns.

Using performance reference compound-corrected polyethylene passive sampler and caged bivalves to measure hydrophobic contaminants of concern in urban coastal seawaters

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ABSTRACT

Low-density polyethylene (PE) passive samplers containing performance reference compounds (PRCs) were deployed at multiple depths in two urban coastal marine locations to estimate dissolved concentrations of hydrophobic organic contaminants (HOCs), including dichlorodiphenyltrichloroethane (DDT) and its metabolites, polychlorinated biphenyl (PCB) congeners, and polybrominated flame retardants. PE samplers pre-loaded with PRCs were deployed at the surface, mid-column, and near bottom at sites representing the nearshore continental shelf off southern California (Santa Monica Bay, USA) and a mega commercial port (Los Angeles Harbor). After correcting for fractional equilibration using PRCs, concentrations ranged up to 100 pg L^{-1} for PCBs and polybrominated diphenyl ethers (PBDEs), 500 pg L^{-1} for DDMU and 300 pg L^{-1} for DDNU, and to 1000 pg L^{-1} for p,p^{1}-DDE. Seawater concentrations of DDTs and PCBs increased with depth, suggesting that bed sediments serve as the source of water column HOCs in Santa Monica Bay. In contrast, no discernable pattern between surface and near-bottom concentrations in Los Angeles Harbor was observed, which were also several-fold lower (DDTs: 45–300 pg L^{-1}, PCBs: 5– 50 pg L^{-1}) than those in Santa Monica Bay (DDTs: 2–1100 pg L^{-1}, PCBs: 2–250 pg L^{-1}). Accumulation by mussels co-deployed with the PE samplers at select sites was strongly correlated with PE-estimated seawater concentrations, providing further evidence that these samplers are a viable alternative for monitoring of HOC exposure. Fractional equilibration observed with the PRCs increased with decreasing PRC molar volume indicating the importance of target compound physicochemical properties when estimating water column concentrations using passive samplers *in situ*.

CITATION

Joyce, A.S., M.S. Pirogovsky, R.G. Adams, W. Lao, D. Tsukada, C.L. Cash, J.F. Haw, K.A. Maruya. 2015. Using performance reference compound-corrected polyethylene passive samplers and caged bivalves to measure hydrophobic contaminants of concern in urban coastal seawaters. *Chemosphere* 127:10-17.

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A passive sampler based on solid phase microextraction (SPME) for sediment-associated organic pollutants: Comparing freely-dissolved concentration with bioaccumulation

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ABSTRACT

The elevated occurrence of hydrophobic organic chemicals (HOCs) such as polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCBs) and legacy organchlorine pesticides (e.g. chlordane and DDT) in estuarine sediments continues to pose challenges for maintaining the health of aquatic ecosystems. Current efforts to develop and apply protective, science-based sediment quality regulations for impaired waterbodies are hampered by non-concordance between model predictions and measured bioaccumulation and toxicity. A passive sampler incorporating commercially available solid phase microextraction (SPME) fibers was employed in lab and field studies to measure the freely dissolved concentration of target HOCs (C_{free}) and determine its suitability as a proxy for bioaccumulation. SPME deduced C_{free} for organochlorines was highly correlated with tissue concentrations (C_b) of *Macoma* and *Nereis* spp. co-exposed in laboratory microcosms containing both spiked and naturally contaminated sediments. This positive association was also observed *in situ* for endemic bivalves, where SPME samplers were deployed for up to 1 month at an estuarine field site. The concordance between C_b and C_{free} for PAH was more variable, in part due to likely biotransformation by model invertebrates. These results indicate that SPME passive samplers can serve as a proxy for bioaccumulation of sediment-associated organochlorines in both lab and field studies, reducing the uncertainty associated with model predictions that do not adequately account for differential bioavailability.

CITATION

Maruya, K.A., W. Lao, D. Tsukada, D. Diehl. 2015. A passive sampler based on solid phase microextraction (SPME) for sediment-associated organic pollutants: Comparing freely-dissolved concentration with bioaccumulation. *Chemosphere* 137:192-197.

SCCWRP Journal Article #0879
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A tiered assessment framework to evaluate human health risk of contaminated sediment

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ABSTRACT

For sediment contaminated with bioaccumulative pollutants (e.g., PCBs and organochorine pesticides), human consumption of seafood that have bioaccumulated sediment-derived contaminants is a well-established exposure pathway. Historically, regulation and management of this bioaccumulation pathway has focused on site-specific risk assessment. The state of California (USA) is supporting the development of a consistent and quantitative sediment assessment framework to aid in interpreting a narrative objective protecting human health. The conceptual basis of this framework focuses on two key questions: (1) Do observed pollutant concentrations in seafood from a given site pose unacceptable health risks to human consumers? (2) Is sediment contamination at a site a significant contributor to seafood contamination? The first question is evaluated by interpreting seafood tissue concentrations at the site, based on health risk calculations. The second question is evaluated by interpreting site-specific sediment chemistry data using a food web bioaccumulation model. The assessment framework includes three tiers (screening assessment, site assessment, and refined site assessment), which enables the assessment to match variations in data availability, site complexity, and study objectives. The second and third tiers use a stochastic simulation approach, incorporating information on variability and uncertainty of key parameters, such as seafood contaminant concentration and consumption rate by humans. The framework incorporates site-specific values for sensitive parameters and statewide values for difficult to obtain or less sensitive parameters. The proposed approach advances risk assessment policy by incorporating local data into a consistent region-wide problem formulation, applying best available science in a streamlined fashion.

CITATION

Greenfield, B.K., A.R. Melwani, S.M. Bay. 2015. A tiered assessment framework to evaluate human health risk of contaminated sediment. *Integrated Environmental Assessment and Management* 11:459-473.

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Fish consumption as a driver of risk-management decisions and human health-based water quality criteria

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ABSTRACT

The use and interpretation of fish consumption surveys and interviews, the application of fish consumption rates for sediment evaluation and cleanup, and the development of human health water quality criteria (HH WQC) are complex and interrelated issues. The present article focuses on these issues using examples from the United States, although the issues may be relevant for other countries. Some key considerations include the fact that there are many types of fish consumption surveys (e.g., 24-h recall surveys, food frequency questionnaires, creel surveys), and these surveys have different advantages and limitations. Identification of target populations for protection, identification of the species and quantities of fish consumed, and determination of bioaccumulation assumptions are important factors when developing water quality and sediment screening levels and standards. Accounting for the cultural importance of fish consumption for some populations is an even more complex element. Discussions about HH WQC often focus only on the fish consumption rate and may not have broad public input. Some states are trying to change this through extensive public participation efforts and use of probabilistic approaches to derive HH WQC. Finally, there are limits to what WQC can achieve. Solutions beyond the establishment of WQC that target toxics reduction from other sources may provide the greatest improvements to water quality and reductions in human health risks in the future.

CITATION

Judd, N., Y. Lowney, P. Anderson, S. Baird, S.M. Bay, J. Breidt, M. Buonanduci, Z. Dong, D. Essig, M.R. Garry, R.C. Jim, G. Kirkwood, S. Moore, C. Niemi, R. O'Rourke, B. Ruffle, L.A. Schaider, D.E. Vidal-Dorsch. 2015. Fish Consumption as a Driver of Risk Management Decisions and Human Health-Based Water Quality Criteria. *Environmental Toxicology and Chemistry* 34(11):2427-2436.

SCCWRP Journal Article #0892
Full text available by request: pubrequest@sccwrp.org

Emulsions produced after oil spills: Their fate in estuaries and effects on the Grass Shrimp, Palaemonetes pugio and Blue Crab, Callinectes sapidus

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ABSTRACT

Stable water-in-oil emulsions, often formed after oil spills, contribute to the difficulties of cleanup due to their persistence and high viscosity. The objectives of the present study were to determine the fate and effects on grass shrimp (*Palaemonetes pugio*) and blue crabs (*Callinectes sapidus*) of such emulsions after they enter estuaries. To achieve this objective, non-emulsified oil and stable emulsions, formed from Kuwait crude oil, were added to estuarine mesocosms, followed by exposure of grass shrimp (*Palaemonetes pugio*) to treated sediments. The polycyclic aromatic hydrocarbon (PAHs) concentrations in the mesocosm with emulsified oil decreased from 284 to 7 µg/g sediment in 56 days, while in the mesocosm with non-emulsified oil the PAHs decreased from 271 to 0.2 µg/g sediment over this same time period. Reproduction parameters (ovary development, embryo production) of grass shrimp were affected as a result of exposure to sediments with emulsified oil, including no embryo production (Day 14 sediments) and reduced embryo production (Day 36 sediments). In contrast, grass shrimp reproduction parameters were not affected after exposure to sediments with the same concentration of non-emulsified oil. It is suggested that the persistence of emulsified oil explains the observed effects. Exposure of grass shrimp embryos to pore water from emulsified oil sediments resulted in significantly more DNA strand breaks and reduced embryo hatching rates compared to reference controls or to sediments with non-emulsified oil. In addition to work with oiled sediments, a histological study was conducted on blue crabs fed food containing emulsified oil. The most notable effect was distended hemocytes with large amounts of glycoproteins in the hepatopancreas. It is speculated that crabs with these distended hemocytes are less able to deal with invading microbes, since crab hemocytes are an important part of the crab's immune system. This study suggests that the entrance of water-in-oil emulsions into estuaries can effect grass shrimp reproduction. Procedures that inhibit emulsion formation, thus preventing emulsified oil from entering estuaries, should be considered after oil spills.

CITATION

Lee, R.F., K.A. Maruya, U. Warttinger, K. Bulski, A.N. Walker. 2014. Emulsions Produced after Oil Spills: Their Fate in Estuaries and Effects on the Grass Shrimp, *Palaemonetes pugio* and Blue Crab, *Callinectes sapidus*. In *Crude Oils: Production, Environmental Impacts and Global Market Challenges*, Valenti, C. (ed), Nova Science Publishers, ISBN 978-1-63117-950-1. p. 1-22.

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Ecotoxicogenomics: Microarray interlaboratory comparability

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ABSTRACT

Transcriptomic analysis can complement traditional ecotoxicology data by providing mechanistic insight, and by identifying sub-lethal organismal responses and contaminant classes underlying observed toxicity. Before transcriptomic information can be used in monitoring and risk assessment, it is necessary to determine its reproducibility and detect key steps impacting the reliable identification of differentially expressed genes. A custom 15K-probe microarray was used to conduct transcriptomics analyses across six laboratories with estuarine amphipods exposed to cyfluthrin-spiked or control sediments (10 days). Two sample types were generated, one consisted of total RNA extracts (Ex) from exposed and control samples (extracted by one laboratory) and the other consisted of exposed and control whole body amphipods (WB) from which each laboratory extracted RNA. Our findings indicate that gene expression microarray results are repeatable. Differentially expressed data had a higher degree of repeatability across all laboratories in samples with similar RNA quality (Ex) when compared to WB samples with more variable RNA quality. Despite such variability a subset of genes were consistently identified as differentially expressed across all laboratories and sample types. We found that the differences among the individual laboratory results can be attributed to several factors including RNA quality and technical expertise, but the overall results can be improved by following consistent protocols and with appropriate training.

CITATION

Vidal-Dorsch, D.E., S.M. Bay, S. Moore, B. Layton, A.C. Mehinto, C.D. Vulpe, M. Brown-Augustine, A. Loguinov, H. Poynton, N. Garcia-Reyero, E.J. Perkins, L. Escalon, N.D. Denslow, C.-D.R. Cristina, T. Doan, S. Shukradas, J. Bruno, L. Brown, G. Van Agglen, P. Jackman, M. Bauer. 2016. Ecotoxicogenomics: Microarray interlaboratory comparability. *Chemosphere* 144, 193-200.

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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, and to test out these tools in pilot studies across California. With the progress demonstrated by these efforts, SCCWRP has been able to develop and vet an overall CEC strategy to guide its research agenda over the next several years. Accomplishments in 2015 include:

» **Monitoring estrogenic chemicals through bioanalytical screening assays:** In an effort to understand whether cell-based assays could be used to screen for estrogenic CECs in receiving waters, SCCWRP and its collaborators completed a laboratory study in 2015 that compared screening response to higher-order effects on fish exposed to estrogen-mimicking chemicals. Results with the inland silverside (*Menidia* spp.), an estuarine species used for environmental monitoring, showed that an increase in bioassay response corresponded to reduced growth of *Menidia*, adding to emerging evidence that bioassays can be linked to meaningful biological impacts on whole organisms. To finish the project, SCCWRP intends to expose *Menidia* to treated wastewater effluent to more closely approximate the mixture of natural and synthetic estrogens that fish are exposed to in receiving waters.

» **Using nontargeted analysis to compare contaminants in birds and marine mammals:** SCCWRP and collaborators completed a nontargeted analysis study in 2015 examining anthropogenic chemicals found in coastal bird eggs as part of the bioaccumulation component of the Southern California Bight 2013 Regional Monitoring Program. Fewer persistent, bioaccumulative compounds were found in bird eggs than in bottlenose dolphins, indicating that marine mammals can serve as particularly effective early-warning sentinels of marine ecosystem health. SCCWRP will continue its efforts to use nontargeted analysis to track contamination, with plans in 2016 to compare nontargeted contaminant profiles – or "fingerprints" – for different marine mammal species that frequent the Southern California coastal ocean.

» **Launching pilot monitoring of CECs statewide:** SCCWRP has begun testing the utility of its CEC monitoring framework to track contaminants in receiving waters across California. SCCWRP in 2015 completed bioanalytical screening of receiving water samples from Southern California watersheds that were collected during the first year of the Southern California Stormwater Monitoring Coalition's three-year regional monitoring pilot study; the next step is to use nontargeted chemical analysis to analyze the samples prioritized by the screening, in an effort to identify CECs that may degrade water quality. SCCWRP in 2015 also completed sampling of popular sport fish in the Russian River watershed that will be analyzed for the presence of CECs; the next steps are to apply SCCWRP's CEC monitoring framework to river water samples that receive wastewater effluent discharge and stormwater runoff from urban and agricultural landscapes.

A tiered, integrated biological and chemical monitoring framework for contaminants of emerging concern in aquatic ecosystems

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ABSTRACT

The chemical-specific risk-based paradigm that informs monitoring and assessment of environmental contaminants does not apply well to the many thousands of new chemicals that are being introduced into ambient receiving waters. We propose a tiered framework that incorporates bioanalytical screening tools and diagnostic nontargeted chemical analysis to more effectively monitor for contaminants of emerging concern (CECs). The framework is based on a comprehensive battery of *in vitro* bioassays to first screen for a broad spectrum of CECs and nontargeted analytical methods to identify bioactive contaminants missed by the currently favored targeted analyses. Water quality managers in California have embraced this strategy with plans to further develop and test this framework in regional and statewide pilot studies on waterbodies that receive discharge from municipal wastewater treatment plants and stormwater runoff. In addition to directly informing decisions, the data obtained using this framework can be used to construct and validate models that better predict CEC occurrence and toxicity. The adaptive interplay among screening results, diagnostic assessment and predictive modeling will allow managers to make decisions based on the most current and relevant information, instead of extrapolating from parameters with questionable linkage to CEC impacts.

CITATION

Maruya, K.A., N.G. Dodder, A.C. Mehinto, N.D. Denslow, D. Schlenk, S.A. Snyder, S.B. Weisberg. A Tiered, Integrated Biological and Chemical Monitoring Framework for Contaminants of Emerging Concern (CECs) in Aquatic Ecosystems. I*ntegrated Environmental Assessment and Management* DOI 10.1002/ieam.1702.

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Nontargeted biomonitoring of halogenated organic compounds in two ecotypes of bottlenose dolphins (Tursiops truncatus) from the Southern California Bight

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ABSTRACT

Targeted environmental monitoring reveals contamination by known chemicals, but may exclude potentially pervasive but unknown compounds. Marine mammals are sentinels of persistent and bioaccumulative contaminants due to their longevity and high trophic position. Using nontargeted analysis, we constructed a mass spectral library of 327 persistent and bioaccumulative compounds identified in blubber from two ecotypes of common bottlenose dolphins (*Tursiops truncatus*) sampled in the Southern California Bight. This library of halogenated organic compounds (HOCs) consisted of 180 anthropogenic contaminants, 41 natural products, 4 with mixed sources, 8 with unknown sources, and 94 with partial structural characterization and unknown sources. The abundance of compounds whose structures could not be fully elucidated highlights the prevalence of undiscovered HOCs accumulating in marine food webs. Eighty-six percent of the identified compounds are not currently monitored, including 133 known anthropogenic chemicals. Compounds related to dichlorodiphenyltrichloroethane (DDT) were the most abundant. Natural products were, in some cases, detected at abundances similar to anthropogenic compounds. The profile of naturally occurring HOCs differed between ecotypes, suggesting more abundant offshore sources of these compounds. This nontargeted analytical framework provided a comprehensive list of HOCs that may be characteristic of the region, and its application within monitoring surveys may suggest new chemicals for evaluation.

CITATION

Shaul, N.J., N.G. Dodder, L.I. Aluwihare, S.A. Mackintosh, K.A. Maruya, S.J. Chivers, K. Danil, D.W. Weller, E. Hoh. 2015. Nontargeted biomonitoring of halogenated organic compounds in two ecotypes of bottlenose dolphins (*Tursiops truncatus*) from the Southern California Bight. *Environmental Science and Technology* 49:1328-38.

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Identifying bioaccumulative halogenated organic compounds using a nontargeted analytical approach: Seabirds as sentinels

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ABSTRACT

Persistent organic pollutants (POPs) are typically monitored via targeted mass spectrometry, which potentially identifies only a fraction of the contaminants actually present in environmental samples. With new anthropogenic compounds continuously introduced to the environment, novel and proactive approaches that provide a comprehensive alternative to targeted methods are needed in order to more completely characterize the diversity of known and unknown compounds likely to cause adverse effects. Nontargeted mass spectrometry attempts to extensively screen for compounds, providing a feasible approach for identifying contaminants that warrant future monitoring. We employed a nontargeted analytical method using comprehensive two-dimensional gas chromatography coupled to time-of-flight mass spectrometry (GC×GC/TOF-MS) to characterize halogenated organic compounds (HOCs) in California Black skimmer (*Rynchops niger*) eggs. Our study identified 111 HOCs; 84 of these compounds were regularly detected via targeted approaches, while 27 were classified as typically unmonitored or unknown. Typically unmonitored compounds of note in bird eggs included tris(4-chlorophenyl)methane (TCPM), tris(4-chlorophenyl) methanol (TCPMOH), triclosan, permethrin, heptachloro-1'-methyl-1,2'-bipyrrole (MBP), as well as four halogenated unknown compounds that could not be identified through database searching or the literature. The presence of these compounds in Black skimmer eggs suggests they are persistent, bioaccumulative, potentially biomagnifying, and maternally transferring. Our results highlight the utility and importance of employing nontargeted analytical tools to assess true contaminant burdens in organisms, as well as to demonstrate the value in using environmental sentinels to proactively identify novel contaminants.

CITATION

Millow, C.J., S.A. Mackintosh, R.L. Lewison, N.G. Dodder, E. Hoh. 2015. Identifying bioaccumulative halogenated organic compounds using a nontargeted analytical approach: seabirds as sentinels. *PLoS One* 10: e0127205.

SCCWRP Journal Article #0876
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/876_IdentifyingBioaccHalogCompNontargetedSeabirds.pdf

Interlaboratory comparison of in vitro bioassays for screening of endocrine disrupting chemicals in recycled water

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ABSTRACT

In vitro bioassays have shown promise as water quality monitoring tools. In this study, four commercially available *in vitro* bioassays (GeneBLAzer® androgen receptor (AR), estrogen receptor-alpha (ER), glucocorticoid receptor (GR) and progesterone receptor (PR) assays) were adapted to screen for endocrine active chemicals in samples from two recycled water plants. The standardized protocols were used in an interlaboratory comparison exercise to evaluate the reproducibility of *in vitro* bioassay results. Key performance criteria were successfully achieved, including low background response, standardized calibration parameters and high intra-laboratory precision. Only two datasets were excluded due to poor calibration performance. Good interlaboratory reproducibility was observed for GR bioassay, with 16-26% variability among the laboratories. ER and PR bioactivity was measured near the bioassay limit of detection and showed more variability (21-54%), although interlaboratory agreement remained comparable to that of conventional analytical methods. AR bioassay showed no activity for any of the samples analyzed. Our results indicate that ER, GR and PR, were capable of screening for different water quality, i.e., the highest bioactivity was observed in the plant influent, which also contained the highest concentrations of endocrine active chemicals measured by LC-MS/MS. After advanced treatment (e.g., reverse osmosis), bioactivity and target chemical concentrations were both below limits of detection. Comparison of bioassay and chemical equivalent concentrations revealed that targeted chemicals accounted for <5% of bioassay activity, suggesting that detection limits by LC-MS/MS for some chemicals were insufficient and/or other bioactive compounds were present in these samples. Our study demonstrated that *in vitro* bioassays responses were reproducible, and can provide information to complement conventional analytical methods for a more comprehensive water quality assessment.

CITATION

Mehinto, A.C., A. Jia, S.A. Snyder, B.S. Jayasinghe, N.D. Denslow, J. Crago, D. Schlenk, C. Menzie, S.D. Westerheide, F.D.L. Leusch, K.A. Maruya. 2015. Interlaboratory comparison of *in vitro* bioassays for screening of endocrine disrupting chemicals in recycled water. *Water Research* 83:303-309.

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Full text available by request: pubrequest@sccwrp.org

Transcriptomic effects-based monitoring for endocrine active chemicals: Assessing relative contribution of treated wastewater to downstream pollution

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Abstract

The present study investigated whether a combination of targeted analytical chemistry information with unsupervised, data-rich biological methodology (i.e., transcriptomics) could be utilized to evaluate relative contributions of wastewater treatment plant (WWTP) effluents to biological effects. The effects of WWTP effluents on fish exposed to ambient, receiving waters were studied at three locations with distinct WWTP and watershed characteristics. At each location, 4 d exposures of male fathead minnows to the WWTP effluent and upstream and downstream ambient waters were conducted. Transcriptomic analyses were performed on livers using 15,000 feature microarrays, followed by a canonical pathway and gene set enrichment analyses. Enrichment of gene sets indicative of teleost brain−pituitary−gonadal−hepatic (BPGH) axis function indicated that WWTPs serve as an important source of endocrine active chemicals (EACs) that affect the BPGH axis (e.g., cholesterol and steroid metabolism were altered). The results indicated that transcriptomics may even pinpoint pertinent adverse outcomes (i.e., liver vacuolization) and groups of chemicals that preselected chemical analytes may miss. Transcriptomic Effects-Based monitoring was capable of distinguishing sites, and it reflected chemical pollution gradients, thus holding promise for assessment of relative contributions of point sources to pollution and the efficacy of pollution remediation.

Citation

Martinovic-Weigelt, D., A.C. Mehinto, G.T. Ankley, N.D. Denslow, L.B. Barber, K.E. Lee, R.J. King, H.L. Schoenfuss, A.L. Schroeder, D.L. Villeneuve. 2015. Transcriptomic Effects-Based Monitoring for Endocrine Active Chemicals: Assessing Relative Contribution of Treated Wastewater to Downstream Pollution. *Environmental Science & Technology* dx.doi.org/10.1021/es404027n.

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Full text available by request: pubrequest@sccwrp.org

Monitoring of constituents of emerging concern (CECs) in California's aquatic ecosystems – Pilot study design and QA/QC guidance

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Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Dodder, N.G., A.C. Mehinto, K.A. Maruya. 2015. Monitoring of Constituents of Emerging Concerns (CECs) in Aquatic Ecosystems: Pilot Study Design and QA/QC Guidance. Technical Report 854. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0854
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/854_CaliforniaCEC_PilotStudy_040315.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 waterbodies, 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 waterbodies. 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 waterbody factors. The second step is to design a framework for assessing the condition of a waterbody, 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 to 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 2015 include:

» **Vetting a science plan to develop nutrient objectives for California's streams:** SCCWRP and its partners in 2015 asked an expert panel to review a science plan that supports the State Water Board's effort to develop nutrient objectives in wadeable streams statewide. The four-member panel concluded that the Science Plan to Support Nutrient Objectives in Wadeable Streams is "thorough and state-of-the-art." In particular, the review panel applauded SCCWRP's plan to use a consensus approach among experts to establish eutrophication indicator ranges that correspond to particular levels of ecological condition, otherwise known as the Biological Condition Gradient (BCG) Model. The experts will use indicator data from stream algae and/or benthic macroinvertebrates to classify stream sites into classes based on their condition. The science plan is part of a three-year effort by the State Water Board to develop nutrient objectives for all of California's wadeable streams.

» **Developing a statewide strategy to monitor HABs:** SCCWRP in 2015 helped lead development of a comprehensive statewide coordination strategy for assessing, communicating about, and managing freshwater harmful algal blooms (HABs) and their associated algal toxins. The California Freshwater Harmful Algal Blooms Assessment and Support Strategy, which has been codified in a report set to be released by the Surface Water Ambient Monitoring Program in 2016, explores responses to HAB events, field assessment and ambient monitoring programs for HABs, and risk assessment for potential HAB events. The cyanotoxins produced by HABs can cause significant impacts and have triggered multiple waterbodies to be placed on federal 303(d) listings of impaired waterbodies. SCCWRP is working to heighten awareness of cyanobacteria, overseeing ongoing monitoring efforts in lakes, estuaries and lagoons across Southern California and co-chairing the Eighth Symposium on Harmful Algae in the U.S., held in 2015 in Long Beach, Calif.

» **Building a model to predict West Coast ocean acidification and hypoxia:** SCCWRP in 2015 partnered with the University of California, Los Angeles, the University of Washington, and the National Oceanic and Atmospheric Administration's Pacific Marine Environmental Laboratory to develop a predictive model examining how the West Coast is impacted by ocean acidification and hypoxia (OAH). The goal of the three-year modeling effort is to help West Coast managers understand which marine habitats are most vulnerable to OAH and to what extent local, land-based sources of pollution are exacerbating coastal OAH conditions. The modeling work involves coupling West Coast physical and biogeochemical ocean models together to ascertain the relative contributions of global carbon dioxide emissions, natural upwelling processes, and nutrients introduced via local discharges on the status and trends of OAH in the California Current System. The model also will be downscaled to the Southern California Bight, Central California, and Oregon coastal regions. SCCWRP already has begun coordinating with the Southern California Bight 2013 Regional Monitoring Program's Nutrients element to conduct the research necessary to validate hydrographic and biogeochemical model output in the Southern California Bight.

Wadeable streams as widespread sources of benthic cyanotoxin production in California, USA

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Abstract

Lentic water bodies and large rivers have long been recognized as being susceptible, under certain conditions, to toxin-producing ("toxigenic") planktonic cyanobacterial blooms. Although benthic cyanobacteria commonly inhabit wadeable (i.e., shallow) streams, little has been published on the potential for cyanotoxin (e.g., microcystin) production in this water body type. Recent research in Monterey Bay, California, USA has linked inland-derived microcystins to numerous sea otter mortalities in the marine environment, a finding that illustrates the negative effects cyanotoxins can have on ecosystem services, even far downstream from their origin, due to fluvial transport. For the present study, surveys of >1200 wadeable stream segments were conducted throughout California during the spring and summer of 2007 through 2013, and revealed a high occurrence of potentially toxigenic benthic cyanobacteria. In addition, benthic microcystins were detected in one-third of sites, where tested (N = 368), based primarily on one-time sampling, from 2011 to 2013 (mean concentration was 46 μg/m2 of stream-bottom). Sites where microcystins were detected spanned a variety of surrounding land-use types, from open space (i.e., undeveloped land) to heavily urbanized/agricultural. Lyngbyatoxin (n = 14), saxitoxins (n = 99), and anatoxin-a (n = 33) were also measured, at subsets of sites, and were also detected, albeit at lower rates than microcystins. Results of this study provide strong evidence that wadeable streams could be significant sources of cyanotoxin inputs to receiving waters, a finding that has implications for the management of drinking water, wildlife, and recreational resources, within both the streams themselves and in downstream rivers, lentic water bodies, and the ocean.

Citation

Fetscher, A.E., M.D.A. Howard, R. Stancheva, R.M. Kudela, E.D. Stein, M.A. Sutula, L.B. Busse, R.G. Sheath. 2015. Wadeable streams as widespread sources of benthic cyanotoxin production in California, USA. *Harmful Algae* 49:105-116.

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Full text available by request: pubrequest@sccwrp.org

Screening assessment of cyanobacteria and cyanotoxins in Southern California lentic habitats

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Abstract

Harmful bloom-forming cyanobacteria (CyanoHABs) and associated toxins are increasingly prevalent world-wide. We conducted a screening-level study to determine if cyanobacteria and associated cyanotoxins were present in Southern California coastal lakes, ponds, and seasonally tidal lagoons. We evaluated waterbody nutrient status and physiochemical parameters, land use, waterbody type, and habitat type, to determine their utility as screening factors for risk of CyanoHAB blooms. One-time grab samples were collected from 30 sites during July–September 2009. Samples were analyzed for phytoplankton taxonomic composition, nutrients, other physiochemical parameters, and three cyanotoxins: microcystins (MCY), anatoxin-a, and cylindrospermopsin. Cyanobacteria was the predominant taxonomic group in most water bodies in this study, and *Microcystis* spp. was the predominant genus in 96% of the study sites. Cyanobacteria were equally prevalent among coastal lagoons, depressional wetlands, and lakes in this study. We detected MCY in high concentrations in 10% of our sites, but neither anatoxin-a nor cylindrospermopsin were detected. All of the MCY-positive sites exceeded California action levels for recreational use and World Health

Organization (WHO) guidance for human health effects. The prevalence of *Microcystis* spp. from all study sites indicates a high potential for MCY in these water bodies, although the one-time toxin grab samples likely underestimated the overall toxicity of these sites. Landscape variables, such as developed land use and dominant habitat type, were not found to be predictive indicators of cyanobacterial dominance. However, because cyanobacteria become consistently dominant when chlorophyll-a levels exceed 15 µg L^{-1}, chlorophyll-a can serve as a significant predictor of MCY.

CITATION

Magrann, T., M.D.A. Howard, M. Sutula, D.S. Boskovic, W.K. Hayes, S.G. Dunbar. 2015. Screening assessment of cyanobacteria and cyanotoxins in Southern California lentic habitats. *Environmental Management and Sustainable Development* 4(2), ISSN 2164-7682.

SCCWRP Journal Article #0891
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/891_ScreeningAssessmentOfSoCalLenticHabitatCynobacteria&Cyanotoxins.pdf

Ocean acidification needs for natural resource managers of the North American west coast

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[4]*Southern California Coastal Water Research Project, Costa Mesa, CA*
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ABSTRACT

Natural circulation patterns along the west coast of North America periodically draw subthermocline, low pH waters into shallow coastal areas. The presence of corrosive, low pH waters, caused by ocean acidification (OA), is frequently observed along the North American west coast. Reduction of global atmospheric CO_2 inputs is the appropriate management focus for decreasing OA, but there are also many management decisions made at regional to local spatial scales that can lessen the exposure to or limit the effects of atmospheric CO_2. Here, we describe these local management actions and identify the science needs that would assist local managers in deciding whether, and how best, to address local OA. Science needs are diverse, but three commonalities emerge. First, managers need a comprehensive monitoring program that expands understanding of spatial and temporal OA patterns and how OA changes influence marine ecosystems. Second, they require mechanistic, process based models that differentiate natural from anthropogenically driven OA patterns and the extent to which local actions would affect OA conditions in context of what is largely a global atmospheric-driven phenomenon. Models present the opportunity to visualize outcomes with and without the changes in management actions included in model scenarios. Third, managers need models that identify which locales are most and least vulnerable to future changes due to OA. Understanding vulnerability will assist managers in better siting facilities (e.g., aquaria) or protecting marine resources. The required monitoring and modeling are all achievable, with much of the necessary research and development already underway. The challenge will be to ensure good and continuing communication between the management community that requires the information and the scientific community that is often hesitant to provide recommendations while uncertainty remains high.

CITATION

Boehm, A.B., M.Z. Jacobson, M.J. O'Donnell, M. Sutula, W.W. Wakefield, S.B. Weisberg, E. Whiteman. 2015. Ocean acidification science needs for natural resource managers of the North American west coast. *Oceanography* 28:170–181.

SCCWRP Journal Article #0867
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/867_OceanAcidifNeeds.pdf

Impacts of coastal acidification on the Pacific Northwest shellfish industry and adaptation strategies implemented in response

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ABSTRACT

In 2007, the US west coast shellfish industry began to feel the effects of unprecedented levels of larval mortality in commercial hatcheries producing the Pacific oyster *Crassostrea gigas*. Subsequently, researchers at Whiskey Creek Shellfish Hatchery, working with academic and government scientists, showed a high correlation between aragonite saturation state (Ω_{arag}) of inflowing seawater and survival of larval groups, clearly linking increased CO_2 to hatchery failures. This work led the Pacific Coast Shellfish Growers Association (PCSGA) to instrument shellfish hatcheries and coastal waters, establishing a monitoring network in collaboration with university researchers and the US Integrated Ocean Observing System. Analytical developments, such as the ability to monitor Ω_{arag} in real time, have greatly improved the industry's understanding of carbonate chemistry and its variability and informed the development of commercial-scale water treatment systems. These treatment systems have generally proven effective, resulting in billions of additional oyster larvae supplied to Pacific Northwest oyster growers. However, significant

challenges remain, and a multifaceted approach, including selective breeding of oyster stocks, expansion of hatchery capacity, continued monitoring of coastal water chemistry, and improved understanding of biological responses will all be essential to the survival of the US west coast shellfish industry.

CITATION

Barton, A., G.G. Waldbusser, R.A. Feely, S.B. Weisberg, J.A. Newton, B. Hales, S. Cudd, B. Eudeline, C.J. Langdon, I. Jefferds, T. King, A. Suhrbier, K. McLaughlin. 2015. Impacts of coastal acidification on the Pacific Northwest shellfish industry and adaptation strategies implemented in response. *Oceanography* 28:146-159.

SCCWRP Journal Article #0865
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/865_CoastalAcidImpactsShellfish.pdf

Getting ocean acidification on decision makers' to-do lists: Dissecting the process through case studies

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ABSTRACT

Much of the detailed, incremental knowledge being generated by current scientific research on ocean acidification (OA) does not directly address the needs of decision makers, who are asking broad questions such as: Where will OA harm marine resources next? When will this happen? Who will be affected? And how much will it cost? In this review, we use a series of mainly US-based case studies to explore the needs of local to international-scale groups that are making decisions to address OA concerns. Decisions concerning OA have been made most naturally and easily when information needs were clearly defined and closely aligned with science outputs and initiatives. For decisions requiring more complex information, the process slows dramatically. Decision making about OA is greatly aided (1) when a mixture of specialists participates, including scientists, resource users and managers, and policy and law makers; (2) when goals can be clearly agreed upon at the beginning of the process; (3) when mixed groups of specialists plan and create translational documents explaining the likely outcomes of policy decisions on ecosystems and natural resources; (4) when regional work on OA fits into an existing set of priorities concerning climate or water quality; and (5) when decision making can be reviewed and enhanced.

CITATION

Cooley, S.R., E.B. Jewett, J. Reichert, L. Robbins, G. Shrestha, D. Wieczorek, S.B. Weisberg. 2015. Getting ocean acidification on decision makers' to-do lists: Dissecting the process through case studies. *Oceanography* 28:198–211.

SCCWRP Journal Article #0868
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/868_GettingAcidfOnList.pdf

Thresholds of adverse effects of macroalgal abundance and sediment organic matter on benthic habitat quality in estuarine intertidal flats

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ABSTRACT

Confidence in the use of macroalgae as an indicator of estuarine eutrophication is limited by the lack of quantitative data on the thresholds of its adverse effects on benthic habitat quality. In the present study, we utilized sediment profile imagery (SPI) to identify thresholds of adverse effects of macroalgal biomass, sediment organic carbon (% OC) and sediment nitrogen (% N) concentrations on the apparent Redox Potential Discontinuity (aRPD), the depth that marks the boundary between oxic near-surface sediment and the underlying suboxic or anoxic sediment. At 16 sites in eight California estuaries, SPI, macroalgal biomass, sediment percent fines, % OC, and % N were analyzed at 20 locations along an intertidal transect. Classification and Regression Tree (CART) analysis was used to identify step thresholds associated with a transition from "reference" or natural background levels of macroalgae, defined as that range in which no effect on aRPD was detected. Ranges of 3–15 g dw macroalgae m^{-2}, 0.4–0.7% OC and 0.05–0.07% N were identified as transition zones from reference conditions across these estuaries. Piecewise regression analysis was used to identify exhaustion thresholds, defined as a region along the stress–response curve where severe adverse effects occur; levels of 175 g dw macroalgae m^{-2}, 1.1% OC and 0.1% N were identified as thresholds associated with a shallowing of aRPD to near zero depths. As an indicator of ecosystem condition, shallow aRPD has been related to reduced volume and quality for benthic infauna and alteration in community structure. These effects have been linked to reduced availability of forage for fish, birds and other invertebrates, as well as to undesirable changes in biogeochemical cycling.

Citation

Sutula, M., L. Green, G. Cicchetti, N. Detenbeck, P. Fong. 2014. Thresholds of Adverse Effects of Macroalgal Abundance and Sediment Organic Matter on Benthic Habitat Quality in Estuarine Intertidal Flats. *Estuaries and Coasts* 37(6):1532-1548.

SCCWRP Journal Article #0895
Full text available by request: pubrequest@sccwrp.org

Subsurface seeding of surface harmful algal blooms observed through the integration of autonomous gliders, moored environmental sample processors, and satellite remote sensing in Southern California

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Abstract

An observational study was performed in the central Southern California Bight in Spring 2010 to understand the relationship between seasonal spring phytoplankton blooms and coastal processes that included nutrient input from upwelling, wastewater effluent plumes, and other processes. Multi-month Webb Slocum glider deployments combined with Monterey Bay Aquarium Research Institute (MBARI) environmental sample processors (ESPs), weekly pier sampling, and ocean color data provided a multidimensional characterization of the development and evolution of harmful algal blooms (HABs). Results from the glider and ESP observations demonstrated that blooms of toxic *Pseudo-nitzschia* sp. can develop offshore and subsurface prior to their manifestation in the surface layer and/or near the coast. A significant outbreak and surface manifestation of the blooms coincided with periods of upwelling, or other processes that caused shallowing of the pycnocline and subsurface chlorophyll maximum. Our results indicate that subsurface populations can be an important source for "seeding" surface *Pseudo-nitzschia* HAB events in southern California.

Citation

Seegers, B.N., J.M. Birch, R. Marin, C.A. Scholin, D.A. Caron, E.L. Seubert, M.D.A. Howard, G.L. Robertson, B.H. Jones. 2015. Subsurface seeding of surface harmful algal blooms observed through the integration of autonomous gliders, moored environmental sample processors, and satellite remote sensing in southern California. *Limnology and Oceanography* 60(3) 754-764.

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The monitoring of harmful algal blooms through ocean observing: The development of the California Harmful Algal Bloom Monitoring and Alert Program

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Abstract

Within California there are several programs for studying and monitoring harmful algal blooms (HABs); however, these programs have been largely uncoordinated with respect to each other. To address this issue, the California Harmful Algal Bloom Monitoring and Alert Program (CalHABMAP) was established in 2008, the outcome of a community-led meeting and organizational effort. CalHABMAP created an integrated, statewide, harmful algal bloom monitoring and alert network by coordinating organizations and researchers currently collecting HAB data and developing a centralized portal for the dissemination of this information. HAB information is made accessible in a form useful to water managers, human and animal health agencies and centers, and to the public. The main goal of HABMAP is to ultimately implement a statewide HAB network and forecasting system for California, and potentially the U.S. West Coast. Specific goals include (1) to design a HAB network that will meet the needs of, and be accessible to, all HAB stakeholders; (2) to create a web portal within the California Ocean Observing System programs, and to act as a mechanism to bring these two programs together. The portal will be a centralized location where HAB data and predictive information can be used by many groups throughout the state; (3) to conduct an economic analysis of the potential impacts of HABs along the California coast; (4) to conduct a comparison of analytical methods for toxin analysis and harmful algae identification and enumeration, and review and disseminate the results through a workshop; (5) to collaborate with the Water Quality Monitoring Council to ensure that HAB information and data are included in, and accessible from, water quality websites. While many of these goals are an ongoing effort, CalHABMAP has succeeded in highlighting the need for a coordinated network and serves as partner for regional and national efforts led by the NOAA National Ocean Service, the Integrated Ocean Observing System, and the NASA Applied Sciences Program.

Citation

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Core principles of the California Current Acidification Network: Linking chemistry, physics, and ecological effects

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Abstract

Numerous monitoring efforts are underway to improve understanding of ocean acidification and its impacts on coastal environments, but there is a need to develop a coordinated approach that facilitates spatial and temporal comparisons of drivers and responses on a regional scale. Toward that goal, the California Current Acidification Network (C-CAN) held a series of workshops to develop a set of core principles for facilitating integration of ocean acidification monitoring efforts on the US West Coast. The recommended core principles include: (1) monitoring measurements should facilitate determination of aragonite saturation state (Ω_{arag}) as the common currency of comparison, allowing a complete description of the inorganic carbon system; (2) maximum uncertainty of ±0.2 in the calculation of Ω_{arag} is required to adequately link changes in ocean chemistry to changes in ecosystem function; (3) inclusion of a variety of monitoring platforms and levels of effort in the network will insure collection of high-frequency temporal data at fixed locations as well as spatial mapping across locations; (4) physical and chemical oceanographic monitoring should be linked with biological monitoring; and (5) the monitoring network should share data and make it accessible to a broad audience.

Citation

McLaughlin, K., S.B. Weisberg, A.G. Dickson, G.E. Hofmann, J.A. Newton, D. Aseltine-Neilson, A. Barton, S. Cudd, R.A. Feely, I.W. Jefferds, E.B. Jewett, T. King, C.J. Langdon, S. McAfee, D. Pleschner-Steele, B. Steele. 2015. Core principles of the California Current Acidification Network: Linking chemistry, physics, and ecological effects. *Oceanography* 28:160–169.

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Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/866_CorePrinAcidNetwork_mclaughlin.pdf

Best practices for autonomous measurement of seawater pH with the Honeywell Durafet pH sensor

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Citation

Martz, T., K. McLaughlin, S.B. Weisberg. 2015. Best Practices for autonomous measurement of seawater pH with the Honeywell Durafet pH sensor. Technical Report 861. California Current Acidification Network. California Current Acidification Network (C-CAN).

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Factors affecting growth of cyanobacteria with special emphasis on the Sacramento-San Joaquin Delta

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Citation

Berg, M., M. Sutula. 2015. Factors Affecting Growth of Cyanobacteria with Special Emphasis on the Sacramento-San Joaquin Delta. Technical Report 869. Southern California Coastal Water Research Project. Costa Mesa, CA.

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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 are typically grown overnight in a lab – to genetic methods capable of rapidly detecting and quantifying microbes via the presence of their genetic material (i.e., DNA or RNA). This genetic technology also has the potential to provide important information about the source of fecal contamination, as specific genetic targets can be used to identify 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 on commensurate risk to public health.

Over the past year, SCCWRP has been pursuing research to examine the relative degradation of source-associated markers compared to fecal indicator bacteria and pathogens, and to develop 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 2015 include:

» **Examining relative degradation rates of source-associated markers, fecal indicator bacteria and pathogens:** Following the release of the California Microbial Source Identification Manual in 2014, SCCWRP and its collaborators embarked on a study in 2015 designed to gauge the relative degradation rates of source-associated markers, fecal indicator bacteria (FIB), and pathogens in sediment. Environmental managers need to know the environmental decay rates of source-associated markers relative to the decay rates and viability for FIB and pathogens, so they can begin using a suite of source-associated genetic markers that have been deemed both sensitive and specific for detection and quantification of aquatic fecal contamination sources. To date, management decisions have been made based on levels of FIB and/or pathogens, not on source-associated markers. The study, which was conducted in both fresh and marine water at field sites in Northern, Central and Southern California under both summer and winter conditions, generated data that are being used to develop models that will inform the results of microbial source identification studies. These data will help determine which beaches may be eligible for quantitative microbial risk assessment studies and possible adoption of site-specific water quality objectives.

» **Quantifying the risk of illness to surfers from recreational water contact following rain events:** SCCWRP and its collaborators in 2015 completed the second and final phase of an epidemiology study at San Diego County beaches that will assess whether surfers' health risks increase when entering the ocean, if this risk increases more after it rains, and if this health risk correlates with the fecal indicator bacteria that water-quality managers traditionally have measured. More than 500 surfers were recruited during the second phase of the study, building on the 400-plus surfers recruited in 2014. Collectively, the study participants logged more than 10,000 exposure days, with nearly one-third of these exposure days during or immediately following wet weather. In addition, more than 800 water samples were collected for analysis of fecal indicator bacteria, human and non-human source markers, or pathogens. Researchers are analyzing this data to assess whether current water quality standards protect public health and, if not, what alternative thresholds could be developed using a quantitative microbial risk assessment (QMRA) approach; the use of QMRA for this study marks the first such application at a marine beach following wet weather.

» **Developing a mobile instrument to rapidly enumerate fecal indicator bacteria at high-risk beaches:** SCCWRP and its collaborators in 2015 completed development of a handheld prototype device capable of rapidly enumerating fecal indicator bacteria in a water sample using droplet digital PCR (polymerase chain reaction). The device, which uses the same digital PCR technology that is used in laboratory-based systems, quantifies the amount of genetic material from a purified fecal indicator bacteria DNA sample. By allowing field staff to make near real-time measurements on the beach, rather than being forced to wait while the samples are transported to a central processing laboratory, warnings will be able to be issued sooner to protect ocean bathers from exposure to waterborne pathogens. Also with this field method, technicians will be able to improve microbial source tracking by tracing bacterial contamination to its source. The next steps are to marry the digital PCR module to a sample acquisition and preparation module that will concentrate and lyse bacteria from water samples and then deliver them to the digital PCR module for quantification.

Droplet digital PCR for simultaneous quantification of general and human-associated fecal indicators for water quality assessment

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ABSTRACT

Despite wide application to beach water monitoring and microbial source identification, results produced by quantitative PCR (qPCR) methods are subject to bias introduced by reliance on quantitative standards. Digital PCR technology provides direct, standards-free quantification and may potentially alleviate or greatly reduce other qPCR limitations such as difficulty in multiplexing and susceptibility to PCR inhibition. This study examined the efficacy of employing a duplex droplet digital PCR (ddPCR) assay that simultaneously quantifies *Enterococcus* spp. and the human fecal-associated HF183 marker for water quality assessment. Duplex ddPCR performance was evaluated side-by-side with qPCR and simplex ddPCR using reference material and 131 fecal and water samples. Results for fecal and water samples were highly correlated between ddPCR and simplex qPCR (coefficients > 0.93, $p < 0.001$). Duplexing *Enterococcus* and HF183 in qPCR led to competition and resulted in non-detection or underestimation of the target with low concentration relative to the other, while results produced by simplex and duplex ddPCR were consistent and often indistinguishable from one another. ddPCR showed greater tolerance for inhibition, with no discernable effect on quantification at inhibitor concentrations one to two orders of magnitude higher than that tolerated by qPCR. Overall, ddPCR also exhibited improved precision, higher run-to-run repeatability, similar diagnostic sensitivity and specificity on the HF183 marker, but a lower upper limit of quantification than qPCR. Digital PCR has the potential to become a reliable and economical alternative to qPCR for recreational water monitoring and fecal source identification. Findings from this study may also be of interest to other aspects of water research such as detection of pathogens and antibiotic resistance genes.

CITATION

Cao, Y., M.R. Raith, J.F. Griffith. 2014. Droplet digital PCR for simultaneous quantification of general and human-associated fecal indicators for water quality assessment. *Water Research* 70:337-349.

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Factors affecting the relationship between quantitative polymerase chain reaction (qPCR) and culture-based enumeration of Enterococcus in environmental waters

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ABSTRACT

Aims: To determine the extent to which discrepancies between qPCR and culture-based results in beach water quality monitoring can be attributed to: (i) within-method variability, (ii) between-method difference within each method class (qPCR or culture) and (iii) between-class difference.

Methods and Results: We analysed 306 samples using two culture-based (EPA1600 and Enterolert) and two qPCR (Taqman and Scorpion) methods, each in duplicate. Both qPCR methods correlated with EPA1600, but regression analyses indicated approximately 0.8 $\log_{10}$ unit overestimation by qPCR compared to culture methods. Differences between methods within a class were less than half of this and were minimal for between-replicate within a method.

Using the 104 *Enterococcus* per 100 ml management decision threshold, Taqman qPCR indicated the same decisions as EPA1600 for 87% of the samples, but indicated beach posting for unhealthful water when EPA1600 did not for 12% of the samples. After accounting for within-method and within-class variability, 8% of the samples exhibited true between-class discrepancy where both qPCR methods indicated beach posting while both culture methods did not.

Conclusion: Measurement target difference (DNA vs growth) accounted for the majority of the qPCR-vs-culture discrepancy, but its influence on monitoring application is outweighed by frequent incorrect posting with culture methods due to incubation time delay.

Significance and Impact of the Study: This is the first study to quantify the frequency with which culture-vs-qPCR discrepancies can be attributed to target difference - vs - method variability.

Citation

Raith, M.R., D.L. Ebentier, Y. Cao, J.F. Griffith, S.B. Weisberg. 2013. Factors affecting the relationship between quantitative polymerase chain reaction (qPCR) and culture-based enumeration of *Enterococcus* in environmental waters. *Journal of Applied Microbiology* doi:10.1111/jam. 12383.

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Small drains, big problems: The impact of dry weather runoff on shoreline water quality at enclosed beaches

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Abstract

Enclosed beaches along urban coastlines are frequent hot spots of fecal indicator bacteria (FIB) pollution. In this paper we present field measurements and modeling studies aimed at evaluating the impact of small storm drains on FIB pollution at enclosed beaches in Newport Bay, the second largest tidal embayment in Southern California. Our results suggest that small drains have a disproportionate impact on enclosed beach water quality for five reasons: (1) dry weather surface flows (primarily from over irrigation of lawns and ornamental plants) harbor FIB at concentrations exceeding recreational water quality criteria; (2) small drains can trap dry weather runoff during high tide, and then release it in a bolus during the falling tide when drainpipe outlets are exposed; (3) nearshore turbulence is low (turbulent diffusivities approximately 10^{-3} m^2 s^{-1}), limiting dilution of FIB and other runoff associated pollutants once they enter the bay; (4) once in the bay, runoff can form buoyant plumes that further limit vertical mixing and dilution; and (5) local winds can force buoyant runoff plumes back against the shoreline, where water depth is minimal and human contact likely. Outdoor water conservation and urban retrofits that minimize the volume of dry and wet weather runoff entering the local storm drain system may be the best option for improving beach water quality in Newport Bay and other urban-impacted enclosed beaches.

Citation

Rippy, M.A., R. Stein, B.F. Sanders, K. Davis, K. McLaughlin, J.F. Skinner, J. Kappeler, S.B. Grant. 2014. Small Drains, Big Problems: The Impact of Dry Weather Runoff on Shoreline Water Quality at Enclosed Beaches. *Environmental Science & Technology* dx.doi.org/10.1021/es503139h.

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Full text available by request: pubrequest@sccwrp.org

Use of dye tracers and qPCR to identify human fecal contamination at Doheny State Beach, Dana Point, CA

Blythe A. Layton, Meredith R. Raith, John F. Griffith

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Citation

Layton, B.A., M.R. Raith, J.F. Griffith. 2015. Use of dye tracers and qPCR to identify human fecal contamination at Doheny State Beach, Dana Point, CA. Technical Report 860. Southern California Coastal Water Research Project. Costa Mesa, CA.

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Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/860_DyeTracersPCRForContamWCov.pdf

Wet and dry weather natural background concentrations of fecal indicator bacteria in San Diego, Orange, and Ventura County, California streams

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Citation

Tiefenthaler, L., M. Sutula, Y. Cao, J. Griffith, M. Raith, C. Beck, R. Christoph, J. Shrake. 2015. Wet and Dry Weather Natural Background Concentrations of Fecal Indicator Bacteria in San Diego, Orange, and Ventura County, California Streams. Technical Report 862. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0862
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/862_StreamFIBs.pdf

Ecohydrology

SCCWRP Accomplishments

Ecohydrology is the study of how human-triggered changes in the frequency, magnitude, and duration of water flows affect ecosystem structure and composition. As water runs off land surfaces with varying magnitude, duration and persistence, these flows can not only directly affect biological communities, but also can trigger stream erosion and deposition that alter the physical structure of waterbodies, which, in turn, can further affect the ability of aquatic systems to support desired plant and animal communities. Past SCCWRP research has 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 associated with flood control, stormwater capture, and water reuse practices.

SCCWRP's ecohydrology research is driven by three major objectives: (1) Understand and predict patterns in key drivers of hydrologic change (e.g. land use, climate change, water use practices), (2) develop tools including statistical and deterministic models to evaluate the relationship between key drivers and changes in flow and related physical and biological responses in the stream, and (3) evaluate the effectiveness of various management actions (e.g., BMPs) and other efforts to reduce or mitigate the impacts of flow modification. BMP evaluation should 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.

Over the past year, SCCWRP has focused its work on developing tools for predicting hydrologic change, which will serve as a precursor to developing flow-ecology relationships. SCCWRP also has supported implementation of hydromodification and alternative compliance programs, and evaluation of environmental offsets through various BMP implementation scenarios. Accomplishments in 2015 include:

» **Developing a suite of models to predict hydrologic change:** In preparation for developing flow ecology relationships that will explain how biology is altered in response to changes in flow patterns across Southern California, SCCWRP in 2015 developed an "ensemble" modeling approach that allows hydrologic change to be modeled at any site where biological assessment data are available. Using this approach, SCCWRP was able to assign one of 35 calibrated and validated models to 820 ungaged bioassessment stream sites across Southern California, based on similarities in catchment properties. Once assigned, flow was modeled at all 820 sites for both existing and historical conditions, generating estimated hydrologic change. In 2016, SCCWRP will use these hydrologic change data and the existing bioassessment data to generate flow-ecology relationships, as well as to evaluate spatial patterns in hydrologic change to inform development of management strategies. SCCWRP and its partners already have begun testing application of the modeling tools to inform stream flow management in the San Diego River Watershed; this case study will allow study participants to gain an understanding of how the flow-ecology analysis can be used to inform management decisions and to troubleshoot challenges and obstacles associated with broad-scale implementation of these tools.

» **Evaluating environmental offsets as a tool for water-quality management:** SCCWRP in 2015 co-developed decision-support tools to optimize water resource management in the Maribyrnong River and Jackson Creek Watersheds in Australia, part of an international effort to learn how similar analysis approaches could be applied to Southern California. A series of environmental offset scenarios was modeled to determine which watershed-scale strategy would be most effective at meeting both water-quality and ecological objectives. Strategies included load reduction, dilution, stormwater capture, and pumping treated wastewater to new locations to maintain desired environmental flows. The optimum strategy depended on whether water-quality or environmental flow requirements took precedence. SCCWRP intends to build on this experience to develop similar analysis and decision-support tools for Southern California watersheds, as these tools could be used to evaluate potential alternative compliance strategies being developed across Southern California.

» **Supporting implementation of hydromodification management strategies:** As stormwater permits have increasingly called on municipalities to develop hydromodification management plans in recent years, SCCWRP has helped guide local managers on a number of fronts, including conducting evaluations of susceptibility of streams to hydromodification effects, collecting data to validate existing models, developing on-site and watershed-based management solutions, and developing monitoring programs. By the end of 2015, SCCWRP had assisted in developing hydromodification monitoring and assessment approaches for San Diego County, worked to incorporate hydromodification assessment into the Southern California Stormwater Monitoring Coalition's regional stream assessment in an effort to improve understanding of the ambient condition and extent of hydromodification, and participated in a technical advisory committee that developed the first alternative compliance program for hydromodification and water-quality management in San Diego County.

Governance issues in developing and implementing offsets for water management benefits: Can preliminary evaluation guide implementation effectiveness?

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Abstract

This article explores governance issues in developing innovative pollutant offset programs by focusing on a case study being piloted at the Gisborne Recycled Water Plant in Jackson Creek, a rural sub-catchment of the Maribyrnong River north of Melbourne, Australia. The article offers preliminary lessons from the ongoing design and anticipated challenges facing this innovative program based on reflections from the literature and project progress to-date. This case exemplifies a form of adaptive governance—an approach well suited to achieving broad sustainability objectives—and for which a nearly assessment is both appropriate and opportune. Adaptive governance is characterized by governmental collaboration with civil society groups, social learning through public participation, and experimentation leading to more flexible policy outcomes. Early assessment affords the possibility of midcourse corrections, drawing on experience acquired elsewhere. We contend that the approach being developed in Victoria through this pilot program has implications beyond the use of recycled wastewater for achieving various social objectives. It may also contribute to the development of an expansive water quality offset framework applicable to point source discharges, nonpoint source pollution, and sewerage overspills. Moreover, the approach can be applied to design of offset systems elsewhere—with appropriate economic savings and effective application to multiple water quality challenges if potential problems are discerned early.

Citation

Feldman, D.L., A. Sengupta, L. Stuvick, E. Stein, V. Pettigrove, M. Arora. 2015. Governance issues in developing and implementing offsets for water management benefits: Can preliminary evaluation guide implementation effectiveness? *WIREs Water* DOI:10.1002/wat2.1061.

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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 has worked 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 is moving increasingly toward identifying and studying 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 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 that historically have gone largely unmonitored. Accomplishments in 2015 include:

» **Developing a cost-effective approach to track wetland extent and distribution:** SCCWRP has demonstrated how to use a new wetland tracking system to evaluate whether land-use changes are achieving state and federal "no net loss" goals for wetlands. In its pilot study, SCCWRP mapped about 4,000 hectares of wetlands and 228 hectares of open water using 2005 as the base year. By extrapolating to the entire state, SCCWRP concluded a wetland density of approximately 9%, which is substantially greater than the 3.5% reported in the 2010 State of the State's Wetland report. SCCWRP attributed this difference to the fact that the State of the State's Wetlands Report did not include streams as part of the overall wetland inventory. The system offers a standardized, cost-effective approach to comprehensively and reliably map wetland areas and track changes in acreage. The system is designed around a probability-based approach that includes guidance on the optimum number and allocation of plots, plot size, and stratification. The goal of the system is to provide environmental managers with consistent, reliable high-quality data – data that historically have been a struggle to effectively and efficiently acquire. The California Water Quality Monitoring Council, which published the mapping protocols, is encouraging all wetland-monitoring programs statewide to use them.

» **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 26% to 40% are considered to be in minimally disturbed "reference" condition, depending on the indicator used to assess condition. Excessive nutrients, variables related to ionic concentration, and direct habitat alternation were the dominant stressors affecting wetland condition, with different assessment indicators being sensitive to different stressors. Depressional wetlands, which include 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.

Wetland ecogenomics – The next generation of wetland biodiversity and functional assessment

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Abstract

Biological monitoring and assessment is routinely used to help answer questions about stream and wetland health or presence of species of interest, such as invasive or sensitive species. Molecular methods, such as traditional DNA barcoding, have been explored as tools to improve resolution and efficiency of biomonitoring programs. Despite the advantages of these tools, they require intensive sample processing (e.g., sorting individual organisms) and can only detect targeted species. Extracting DNA from environmental samples (eDNA), combined with next generation sequencing offers promise by allowing for relatively rapid detection of species presence without the need to sort individual specimens. The integration of next-generation sequencing (NGS), eDNA, and metasystematics for wetland assessment we term wetland ecogenomics. Wetland ecogenomics is already opening new avenues for wetland assessment by allowing for efficient assessment of multiple trophic levels, functional genes, and taxonomically comprehensive community composition as measures of wetland function. Here we discuss the stages necessary for the successful implementation of an ecogenomic approach to wetland monitoring and assessment.

Citation

Gibson, J.F., E.D. Stein, D.J. Baird, C.M. Finlayson, X. Zhang, M. Hajibabaei. 2015. Wetland Ecogenomics – The Next Generation of Wetland Biodiversity and Functional Assessment. *Wetland Science and Practice* 32(1):27-32.

SCCWRP Journal Article #0851
Full text available by request: pubrequest@sccwrp.org

How accurate are probability-based estimates of wetland extent? Results of a California validation study

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Abstract

Estimates of wetland and stream extent and distribution form the basis for state and federal monitoring and management programs and guide policy development decisions. The current default approach, comprehensive mapping, provides the most complete information on extent and distribution but is prohibitively expensive across large geographic areas. In contrast, probabilistic mapping produces statistical estimates of extent and distribution at a fraction of the cost of comprehensive mapping. This study provides a direct comparison to address how well probability based estimates of wetland extent approximate results from comprehensive mapping, and the degree to which inter-mapper variability contributes to overall error in probability-based estimates. Two regions of California were selected based on existence of recent, comprehensive wetland and stream maps. Probabilistic sample plot locations were selected by generalized random tessellation stratified sampling and sample plot maps were produced from the same source imagery as the comprehensive maps. Sample maps were compared for inter-mapper variability, plot-by-plot differences between sample and comprehensive maps, and differences between sample estimates and comprehensive totals. On a plot-by-plot basis differences in mapped wetland area between comprehensive maps and probabilistic sample maps approached 50% in either the positive or negative direction, leading to uncertainty in directly comparing maps derived from these two approaches. With application of standardized protocols and rigorous quality control measures, we were able to achieve a 97% overall accuracy rate between independent mapping teams applying the probabilistic mapping approach. Our results suggest caution when comparing comprehensive and sample based wetland extent estimates and highlight the importance of mapper intercalibration.

Citation

Stein, E.D., L.G. Lackey, J. Brown. 2015. How accurate are probability-based estimates of wetland extent? Results of a California validation study. *Wetlands Ecology and Management* DOI 10.1007/s11273-015-9460-0.

SCCWRP Journal Article #0882
Full text available by request: pubrequest@sccwrp.org

Demonstrating the California Wetland Status and Trends Program: A probabilistic approach for estimating statewide aquatic resource extent, distribution and change over time

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CITATION

Stein, E.D., P. Pendleton, K. O'Connor, C. Endris, J. Adalaars, M. Salomon, K. Cayce, A. Jong. 2015. Demonstrating the California Wetland Status and Trends Program: A Probabilistic Approach for Estimating Statewide Aquatic Resource Extent, Distribution and Change over Time – Pilot Study Results. Technical Report 859. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0859
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/859_StatusAndTrendsDemo.pdf

Estuarine Wetland Monitoring Manual: Application and assessment of USEPA three-tiered monitoring strategy to Southern California coastal wetlands

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CITATION

Johnston, K., I. Medel, S. Anderson, E. Stein, C. Whitcraft, J. Crooks. 2015. California Estuarine Wetland Monitoring Manual (Level 3). Technical Report 880. The Bay Foundation, Southern California Coastal Water Research Project, and California State University, Channel Islands.

SCCWRP Technical Report #0880
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/880_L3EstuarineWetlandManual.pdf

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 the regulated community 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 2015 include:

» **Using statewide monitoring of water-quality protected areas to evaluate management actions**: SCCWRP in 2015 completed a series of analyses on the effectiveness of a $32 million grant program funded by the State Water Board to stop the discharge of pollutants to water-quality protected areas, known as Areas of Special Biological Significance (ASBS). SCCWRP helped guide monitoring efforts for the 14 city and county grantees, which used a variety of best management practices (BMPs) to reduce pollutant loads. Cumulatively, across all 29 BMPs that were evaluated by SCCWRP, the BMPs prevented 250 million liters of runoff, 6.2 metric tons of sediment, and 20 kg of trace metals from reaching ASBS during the study year. SCCWRP also concluded that the most effective BMPs were full-capture devices, such as runoff diversions to the sanitary sewer for treatment, that are able to capture all of the flows and their associated pollutants, preventing them from being discharged directly into the ocean. However, SCCWRP found that these relatively small BMPs are typically only able to treat dry-weather nuisance flows; heavy rainfall is able to generate high water volumes that can overwhelm the diversion. Of the flow-through BMPs that are able to treat much larger wet-weather volumes before discharging directly into ASBS, bioswales were found to be the most effective BMP.

» **Kicking off the second cycle of Regional Watershed Monitoring**: The Southern California Stormwater Monitoring Coalition in 2015 kicked off the second cycle of its Regional Watershed Monitoring Program, a five-year initiative to assess the health of 17 watersheds stretching from Ventura to the U.S.-Mexico border. The second cycle of the integrated, cooperative regional monitoring program expands upon the survey design of the first cycle to include nonperennial streams, a stream type that accounts for the majority of stream miles in Southern California but that has historically gone unmonitored. The second cycle also added a host of new biological indicators (i.e., amphibians and invasive species), constituents of emerging concern, and a focus on engineered channels. The Stormwater Monitoring Coalition, a collaboration of 14 public agencies that includes both regulated and regulatory stormwater agencies, is working to understand which stressors might be responsible for impacts when streams aren't healthy. The first five-year cycle of the survey found that 75% of the region's 4,300 miles of perennial streams had some amount of impact based on measurements of invertebrates, algae, and riparian habitat.

» **Wrapping up elements of Bight '13 Regional Monitoring:** The Southern California Bight 2013 Regional Marine Monitoring Program in 2015 published the first volume of its assessment reports – Sediment Toxicity – and released preliminary results for two other sections. The Sediment Toxicity findings will feed into the Contaminant Impact Assessment element, which collectively involved sampling 350 sites for sediment toxicity, sediment toxicity, benthic infauna and fish. Bight '13 also released preliminary results for its Debris element, which involved collecting more than 1,000 samples to assess the regional extent and magnitude of plastic, and for its Marine Protected Areas element, which involved assessing the impact of fishing and water-quality stressors on the Southern California Bight. The other two Bight '13 elements – Shoreline Microbiology and Nutrients – are still engaged in multi-year sampling efforts that are expected to wrap up in 2016. SCCWRP facilitates Bight regional monitoring in partnership with about 100 other agencies.

Southern California Bight regional monitoring

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ABSTRACT

The Southern California Bight (SCB) is a unique ecological and economic resource, home to some of the most productive coastal ecosystems, but also some of largest pollutant inputs in the United States. Historically, environmental monitoring of the coastal environment has been temporally intensive, but spatially focused on narrow areas closest to regulated discharges, providing a potentially biased perspective of overall coastal sediment quality. Beginning in 1994 and conducted approximately every five years thereafter, nearly 100 regulated, regulatory, non-governmental or academic organizations join forces to implement the SCB Regional Marine Monitoring Program (the Bight Program). The most recent Bight program sampled nearly 400 locations, from the head of tide in coastal estuaries to offshore basins 1000 m in depth, using a probabilistic survey design and measuring multiple indicators of sediment quality including chemistry, toxicity, and infauna. The three indicators were scored using regionally-developed assessment tools, and then combined for an integrated assessment of sediment quality. Results showed that the vast majority of SCB sediments do not have impacted sediment quality, but that not all habitats are in equally good condition. Most of the continental shelf is not impacted, despite the discharge of very large (10^9 L/day) of treated wastewater discharges. In contrast, up to 50% of the area in estuaries and 45% of the area in marinas have impacted sediment quality. These generally quiescent waterbodies receive pollutant inputs from the region's extensively urbanized watersheds and high density of boating activities. Despite the relatively large extent of impacted sediment quality in embayments, sediment quality has been steadily improving in this habitat over the last decade based on surveys dating back to the 1998. The Bight Program has affected management actions in the region by focusing current efforts in habitats most impacted by poor sediment quality, and highlighting the improvements from previous management actions.

CITATION

Schiff, K., D. Greenstein, N. Dodder, D. Gillett. Southern California Bight regional monitoring. *Regional Studies in Marine Science* doi:10.1016/j.rsma.2015.09.003.

SCCWRP Journal Article #0890

Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/890_SouthernCaliforniaBightRegionalMonitoring.pdf

Impact of stormwater discharges on water quality in coastal marine protected areas

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ABSTRACT

Marine protected areas worldwide limit harvest to protect sensitive fisheries, but rarely do they address water quality goals that may have equally demonstrable impacts. California has over 500 coastal shoreline miles of marine protected areas designated as Areas of Special Biological Significance (ASBS), but receives untreated wet weather runoff discharges from over 1600 storm drain outfalls. The goal of this study was to assess the extent and magnitude of water quality impacts in ASBS following storm events. A stratified probabilistic design was used for sampling receiving water shorelines near (discharge) and far (non-discharge) from storm drain outfalls. In general, reasonably good water quality exists in California's ASBS following storm events. Many of the target analytes measured did not exceed water quality standards. The post-storm concentrations of most constituents in discharge and nondischarge strata of ASBS were similar. The three potentially problematic parameters identified were total PAH, chromium, and copper. *Water Environ. Res., 87, 772 (2015)*

CITATION

Schiff, K., B. Luk, D. Gregorio. 2015. Impact of Stormwater Discharges on Water Quality in Coastal Marine Protected Areas. *Water Environment Research* 87(9):772-782.

SCCWRP Journal Article #0885

Full text available by request: pubrequest@sccwrp.org

An assessment of the transport of Southern California stormwater ocean discharges

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Abstract

The dominant source of coastal pollution adversely affecting the regional coastal water quality is the seasonally variable urban runoff discharged via southern California's rivers. Here, we use a surface transport model of coastal circulation driven by current maps from high frequency radar to compute two-year hindcasts to assess the temporal and spatial statistics of 20 southern California stormwater discharges. These models provide a quantitative, statistical measure of the spatial extent of the discharge plumes in the coastal receiving waters, defined here as a discharge's "exposure." We use these exposure maps from this synthesis effort to: (1) assess the probability of stormwater connectivity to nearby Marine Protected Areas, and (2) develop a methodology to estimate the mass transport of stormwater discharges. The results of the spatial and temporal analysis are found to be relevant to the hindcast assessment of coastal discharges and for use in forecasting transport of southern California discharges.

Citation

Rogowski, P.A., E. Terrill, K. Schiff, S.Y. Kim. 2014. An assessment of the transport of southern California stormwater ocean discharges. *Marine Pollution Bulletin* dx.doi.org/10.1016/j.marpolbul.2014.11.004.

SCCWRP Journal Article #0840
Full text available by request: pubrequest@sccwrp.org

Bioassessment of perennial streams in Southern California: A report on the first five years of the Stormwater Monitoring Coalition's regional stream survey

Raphael D. Mazor

Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Mazor, R.D. 2015. Bioassessment of Perennial Streams in Southern California: A Report on the First Five Years of the Stormwater Monitoring Coalition's Regional Stream Survey. Technical Report 844. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0844
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/844_SoCalStrmAssess.pdf

Proposition 84 Grant Evaluation Report: Assessing pollutant reductions to areas of biological significance

Kenneth Schiff, Jeff Brown

Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Schiff, K., J. Brown. 2015. Proposition 84 Grant Evaluation Report: Assessing Pollutant Reductions to Areas of Biological Significance. Technical Report 858. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0858
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/858_ASBS_BMPRep.pdf

Near-coastal water quality at reference sites following storm events

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[3]Applied Marine Sciences, Santa Cruz, CA

Citation

Schiff, K., J. Brown, S. Trump, D. Hardin. 2015. Near-Coastal Water Quality at Reference Sites Following Storm Events. Technical Report 853. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0853
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/853_ASBS_Ref.pdf

Bioassessment survey of the Stormwater Monitoring Coalition workplan for years 2015 through 2019 Version 1.0

Raphael D. Mazor

Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Mazor, R. 2015. Bioassessment Survey of the Stormwater Monitoring Coalition: Workplan for Years 2015 through 2019, Version 1.0. Technical Report 849. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0849
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/849_SMCWorkplan2015.pdf

Characterization of the rocky intertidal ecological communities associated with Northern California areas of special biological significance

Peter T. Raimondi, Maya George, Melissa Redfield, Sara Worden, Rachael Williams, Nate Fletcher, Laura Anderson, Dave Lohse, Rani Gaddam

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CITATION

Raimondi, P.T., M. George, M. Redfield, S. Worden, R. Williams, N. Fletcher, L. Anderson, D. Lohse, R. Gaddam. 2015. Characterization of the rocky intertidal ecological communities associated with Northern California Areas of Special Biological Significance. Technical Report 855. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0855
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/855_ASBSNCalRockyIntWCover.pdf

Areas of special biological significance: Northern California bioaccumulation monitoring

Nathan Dodder, Kenneth Schiff

Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Dodder, N., K. Schiff. 2015. Areas of Special Biological Significance: Northern California Bioaccumulation Monitoring. Technical Report 857. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0857
Full text available online:http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/857_ASBSNorCal_Bioacc.pdf

North Coast areas of Special Biological Significance Regional Monitoring Program: First year results

Kenneth Schiff, Jeff Brown

Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Schiff, K., J. Brown. 2015. North Coast Areas of Special Biological Significance Regional Monitoring Program: First Year Results. Technical Report 856. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0856
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/856_NorCalWQRepWCovAndApp.pdf

South coast areas of Special Biological Significance Regional Monitoring Program Year 2 results

Kenneth Schiff, Jeff Brown

Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Schiff, K., J. Brown. 2015. South Coast Areas of Special Biological Significance Regional Monitoring Program Year 2 Results. Technical Report 852. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0852
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/852_SouthCoastASBS_FinalRep.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 and analysis of water-quality monitoring data. To effectively use data, the approach that scientists take to acquiring, managing and assessing data must be well-documented, so that data are reproducible, consistent and comparable among the many organizations that acquire, share and aggregate this data. Increasingly, environmental managers also are demanding sophisticated approaches to visualizing data 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 changing conditions 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 for data acquisition and analysis, these 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 2015 include:

» **Developing mobile apps for acquisition of environmental data:** SCCWRP in 2015 completed a variety of custom mobile app software projects to enhance data collection capabilities in the field. For example, SCCWRP designed an Android tablet app as part of a year-long fish consumption study for San Diego Bay to collect GPS location, interview responses, and photographs of fish, and then to transmit this data daily to SCCWRP; monthly progress reports can be automatically generated from the data. SCCWRP also developed a prototype "app wizard" web-based interface to streamline the process by which app software for both the Android and Apple platforms is programmed to collect data; this tool, which allows associated databases to automatically receive data without custom programming, will facilitate more rapid deployment of mobile data collection apps for future studies. SCCWRP also improved upon prototype application software that extends mobile platforms to include support for low-cost, Bluetooth wireless water quality probes. The software aspect proved successful in accessing and submitting data to SCCWRP, although improving the calibration, reliability and data quality for the selected low-cost probes remains a work in progress.

» **Paving the way for mobile microscopy:** SCCWRP and its partners in 2015 demonstrated that a low-cost, field-portable microscope that uses a smartphone as the viewfinder can effectively identify aquatic algae and diatoms, without the need to collect and return samples to the lab for benchtop analysis. The CellScope Aquatic, created by a laboratory at the University of California, Berkeley, was distributed to several research partners, who successfully deployed the prototype device to capture high-quality imagery in the field on their own smartphones. Given these successes, SCCWRP in 2015 launched a follow-up project that seeks to use automated image processing methods to assist in the assessment and classification of organisms captured by the CellScope Aquatic. SCCWRP's goal is to develop software that recognizes a number of distinct image features – including shapes, movements and recognition patterns – to dramatically speed up data analysis, especially for high volumes of images.

» **Visualizing and analyzing Bight data via a biointegrity tool:** SCCWRP and the newly formed Commission's Technical Advisory Group (CTAG) Analysis and Visualization Users Group kicked off a project in 2015 to build a fish and invertebrate biointegrity tool to visually analyze and compare data collected from across the Southern California Bight. The tool, which will allow SCCWRP member agencies to view their own data and compare this data to other regions of the Bight, is the first project to be undertaken by the CTAG Analysis and Visualization Users Group, which was formed in 2015 to help member agencies pool their skills and resources to develop analysis and visualization tools. The biointegrity tool will use summary statistics, maps and graphs to examine a number of parameters, including trends, diversity, richness and class size. Initially, the tool will feature analyses developed in 2013 by the Trawl element of the Southern California Bight Regional Monitoring Program. Eventually, other types of data will be incorporated, including grain size, biomass, and debris.

Extending Esri Geoportal Server to meet the needs of the West Coast Ocean Data Network and inform regional ocean management

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Abstract

Lack of accessibility to geospatial data by coastal resource managers has been identified at the regional and national levels as a hurdle to improved ecosystem-based management in the United States. The West Coast Ocean Data Portal (http://portal.westcoastoceans.org) is a project of the West Coast Governors Alliance on Ocean Health to address this problem by working to increase discovery and connectivity of coastal and ocean data users and systems to better inform West Coast ocean health decisions. The West Coast Ocean Data Network is a community of practice connecting West Coast data managers and users to develop best practices for regional data sharing. We demonstrate the West Coast Ocean Data Portal and the strategy for using Esri Geoportal Server software to selectively harvest, curate, and publish access to data resources through a compelling portal experience that is customizable and can integrate novel technologies to inform regional ocean management.

Citation

Hallenbeck, T., T. Welch, S.J. Steinberg, A. Lanier. 2015. Extending Esri Geoportal Server to Meet the Needs of the West Coast Ocean Data Network and Inform Regional Ocean Management. pp. 171-184 in: Dawn J. Wright (ed.), *Ocean Solutions Earth Solutions*. Esri Press. Redlands, CA.

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A GIS Tool to compute a pollutant exposure index for the Southern California Bight

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Abstract

Southern California marine ecosystems face a variety of threats to their integrity and health as a result of their proximity to urbanized areas. These threats may be direct, through fishing and resource extraction, or indirect, through exposure to anthropogenic pollutants. Two primary sources of anthropogenic pollutants are treated wastewater, released by publicly owned treatment works through ocean outfalls, and freshwater runoff contained in urban river plumes. We developed a geospatial tool using ArcGIS software to calculate a pollutant exposure index for the Southern California Bight. The pollutant exposure index quantifies long-term exposure to potentially harmful pollutants emanating from these two sources. Recent studies on the dispersal of plumes have resulted in high quality spatial datasets that predict plume occurrence frequencies as point grids around publicly owned treatment works and river mouths throughout the region. We multiplied the plume frequency values with data on average annual discharge rates, initial dilution factors, and concentration of chemicals in discharges to calculate total exposure to pollutants at each location. Using this approach, we developed maps of the distribution of three important plume constituents: dissolved inorganic nitrogen in the form of nitrate and nitrite, total suspended solids, and copper. A series of Python scripts was created to facilitate geoprocessing of the exposure data and calculate the final pollutant exposure index raster, including: (1) creating exposure rasters for each pollutant and source using inverse distance weighting, (2) summing publicly owned treatment works and river plume exposure rasters for each pollutant and normalizing each raster to the maximum exposure value, and (3) creating the pollutant exposure index by summing pollutant exposure rasters and normalizing again to provide values ranging from zero to one. The resulting georeferenced pollutant exposure index raster may be used with other spatial data to examine relative pollution risk for any area of interest within the mapped region. The pollutant exposure index will be incorporated into an ongoing study to examine relative risks posed to marine habitats by pollutants and pressure from fishing.

Citation

Schaffner, R.A., S.J. Steinberg, K.C. Schiff. 2015. A GIS Tool to Compute a Pollutant Exposure Index for the Southern California Bight. pp. 171-184 in: Dawn J. Wright (ed.), *Ocean Solutions Earth Solutions*. Esri Press. Redlands, CA.

SCCWRP Journal Article #0874
Full text available by request: pubrequest@sccwrp.org

San Diego Integrated Regional Water Management Data Management System basic design recommendations

Steven J. Steinberg, Marlene Hanken

Southern California Coastal Water Research Project Authority, Costa Mesa, CA

CITATION

Steinberg, S.J., M. Hanken. 2015. San Diego Integrated Regional Water Management Data Management System Basic Design Recommendations. Technical Report 878. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0878
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/878_SanDiegoWaterDataManagementRecommendations.pdf

Enhancing the vision for managing California's environmental information

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CITATION

Azimi-Gaylon, S., S. Fong, P. Goodwin, T. Hale, G. Isaac, A. Osti, F. Shilling, T. Slawecki, S. Steinberg, M. Tompkins, L. Videmsky. 2015. Enhancing the Vision for Managing California's Environmental Information. Technical Report 884. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0884
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/884_EnhancingVisionForManagingCA_EnvInfo.pdf

EMERGING RESEARCH AND MEMBER AGENCY SUPPORT

SCCWRP Accomplishments

Although most of SCCWRP's research programs fall into one of its nine thematic research areas, SCCWRP continually reassesses its core research agenda to ensure it is effectively meeting the needs of its 14 member agencies. Consequently, some of the research investments that SCCWRP makes represent investments in new and emerging research areas that have yet to grow into a thematic focus area. Other research investments fall into a category known as member agency support, in which SCCWRP works to address topics of immediate interest to the member agencies that may not be likely to grow into full-scale research programs.

Among SCCWRP's emerging research areas, the most prominent is climate change. As the atmosphere and ocean warm and trigger more climate extremes and global changes to water chemistry, scientists must work to identify, evaluate, refine and implement effective mitigation and preparedness measures. SCCWRP already is making scientific contributions to these efforts, primarily associated with ocean acidification, a phenomenon caused by oceanic assimilation of atmospheric carbon dioxide. Two SCCWRP scientists were selected to serve on a U.S. West Coast expert advisory panel that is developing recommendations for managing ocean acidification and hypoxia (OAH). The panel, formed at the request of the three West Coast governors and the British Columbia prime minister, will culminate its deliberations by publishing a series of technical reports in 2016 that summarize the state of the science and identifying management options available to address OAH. SCCWRP also is working to develop coupled physical-biogeochemical models for the West Coast that are intended to provide managers with the ability to assess the likely effectiveness of various local management strategies for reducing OAH-triggered stress (see the Eutrophication research theme). Finally, SCCWRP is developing predictive models intended to help coastal managers assess the impacts of sea-level rise on coastal wetland areas.

Additional accomplishments in 2015 include:

» **Evaluating next-generation ocean pH monitoring technologies:** SCCWRP in 2015 partnered with its four wastewater treatment member agencies to evaluate whether ocean pH monitoring instruments developed through an international XPRIZE competition can be used effectively for nearshore regulatory monitoring in the Southern California Bight. SCCWRP and its member agencies are evaluating four pH sensor prototypes side by side with existing pH monitoring methods during routine Bight monitoring. The goal is to help the XPRIZE contestants improve upon their pH profiling designs to create viable alternatives to glass electrodes, which are the standard pH profiling instruments used for compliance assessments. SCCWRP has demonstrated that glass electrodes cannot track pH changes at the level of precision required to ensure compliance with California's Ocean Plan Standard, which mandates that ocean pH must not be changed by more than ±0.2 pH units from that which occurs naturally.

» **Reviewing California's environmental laboratory accreditation program:** SCCWRP in 2015 assembled a five-member Expert Review Panel to develop recommendations for improving the State's Environmental Laboratory Accreditation Program (ELAP), which is responsible for accrediting the nearly 700 laboratories that produce data submitted to the State as part of regulatory compliance programs. The goal of ELAP is to ensure that data are of acceptable quality for use in environmental decision-making. The panel, which was facilitated by SCCWRP under contract from the State Water Board, released a comprehensive report in 2015 outlining a series of recommended reforms falling into five main themes: establishing a management system, adopting laboratory accreditation standards, ensuring relevant analytical methods, expanding resources and enhancing communication. SCCWRP intends to reconvene the panel in 2017 to assess ELAP's progress in implementing the panel's recommendations.

» **Developing protocols to assess water-quality oxygen standards:** SCCWRP in 2015 facilitated development of a protocol for assessing whether wastewater treatment agencies have achieved compliance regarding California's water-quality standards for oxygen in the ocean environment. The standards require no more than a 10% deviation from natural conditions, but wastewater treatment agencies lacked guidance on what constitutes "natural conditions." SCCWRP worked with its wastewater treatment member agencies and the State Water Board to reach agreement on a fair and impartial compliance assessment protocol. SCCWRP also developed an assessment algorithm that allows wastewater treatment agencies to enter their monitoring data into a computer program to determine compliance. The computer program ensures consistency across Southern California discharges.

Findings and recommendations by the Expert Review Panel for the State of California's Environmental Laboratory Accreditation Program Year One final report

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CITATION

Phelps, L., J. Adelson, S. Arms, M. Miller, D. Speis. 2015. Findings and Recommendations by the Expert Review Panel for the State of California's Environmental Laboratory Accreditation Program Year One Final Report. Technical Report 887. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0887
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/887_ELAPReviewYr1.pdf

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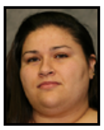

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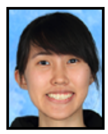

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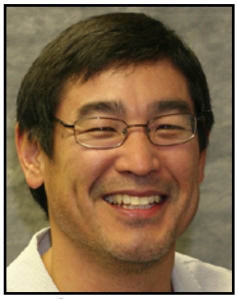
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