SCCWRP

2019-2020 ANNUAL REPORT

Two decades of stormwater management

Southern California's regional investments in research and monitoring are paving the way for improved waterway health

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Applying next-generation science to aquatic ecosystems management

Welcome to the interactive version of SCCWRP's 2019-2020 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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A field crew for the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program collects data at a stream site in the Santa Monica Mountains. SCCWRP has helped stormwater managers use regional monitoring to paint rich, encompassing portraits of the overall ecological health of the region's inland waterways. **Page 10**

Accomplishments with journal abstracts

People

Southern California Coastal Water Research Project 2019-2020 Annual Report

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Cover photo
Runoff flows through a bioswale along a roadway in Orange County. SCCWRP is working to help Southern California's stormwater management community optimize the effectiveness of solutions like bioswales for treating contamination in runoff.

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Snapshot of Success

Steps taken by SCCWRP to improve aquatic science research and water-quality management in 2019-2020

1 Scientific credibility

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

SCCWRP can more effectively transition science into application when the agency engenders 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 **2.6** 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. **Page 29**

» 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 an average of **1,874** times annually over the past two years, according to Web of Science statistics, which represents a **10%** increase in the number of citations since 2018.

2 Scientific consensus-building

Goal: Promote consensus-building through scientific collaboration and leadership

The most expeditious path for the water-quality 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

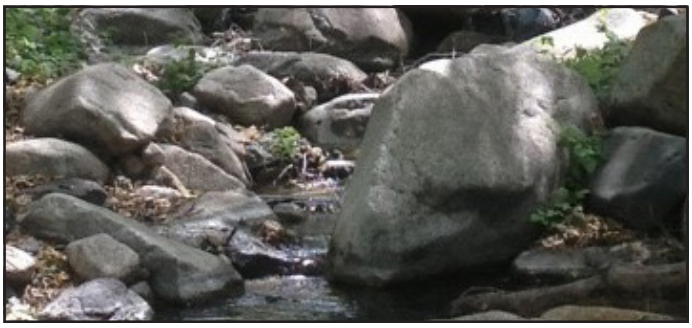
SCCWRP scientific staff held **150** leadership roles with professional societies, advisory committees and scientific journals in 2019 and 2020. **Page 79**

» Collaboration

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

Accomplishment

SCCWRP published scientific articles and reports with **185** different institutions in 2019 and 2020. **Page 29**



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

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3 Management influence

Goal: Positively influence decision-making and actions by the end-user water-quality management community

Scientific credibility and consensus-building are important waypoints along SCCWRP's journey to produce science that positively influences management. The feature articles in this report chronicle SCCWRP's regional investments in stormwater research and monitoring to help reduce contamination in runoff and protect the health of waterways.

» Developing monitoring capabilities

SCCWRP enhances and extends the value of environmental monitoring by developing best-in-class strategies, tools and regional monitoring programs.

» Understanding reasons for degradation

SCCWRP answers key "why" questions about environmental degradation by investigating causes and origins of stress on aquatic systems.

» Optimizing management solutions

SCCWRP boosts the effectiveness of management actions and decisions by methodically developing, testing and vetting emerging science.

Accomplishment

SCCWRP has developed novel, biology-based approaches for monitoring stream health that have generated unprecedented management insights into the ecological condition of the region's waterways. **Page 10**

Accomplishment

SCCWRP has developed novel methods for more precisely pinpointing the origins of human fecal contamination – one of the most vexing, ubiquitous challenges stormwater managers face. **Page 16**

Accomplishment

SCCWRP has built foundational understanding of contamination in runoff that is informing how managers optimally treat runoff and improve water quality. **Page 23**

4 Long-term support

Goal: Provide technical support and expertise to SCCWRP's 14 member agencies to maximize their adoption and use of science

While influencing management decision-making is a signature SCCWRP accomplishment, SCCWRP maximizes the effectiveness of its influence by providing long-term guidance and assistance to its 14 member agencies.

» Training

SCCWRP develops user-friendly instruction materials and conducts hands-on training to ensure managers are properly educated about new tools and technologies.

» Intercalibration

SCCWRP facilitates intercalibration and quality-assurance exercises to ensure managers can demonstrate proficiency using new tools and technologies.

» Vetting

SCCWRP facilitates case studies and expert advisory committees to fully vet new tools and technologies.

» Outreach

SCCWRP conducts outreach activities to ensure managers and stakeholders buy into and fully embrace new approaches and technologies.

SCCWRP prides itself on the long-term support it provides to its member agencies.

Accomplishment

SCCWRP staff spent more than **20,000** person-hours in 2019 and 2020 providing implementation support to member agencies.

Director's Message

A watershed moment for SCCWRP

This year's Annual Report recognizes a major milestone for SCCWRP: It's been 20 years since SCCWRP formally engaged Southern California's stormwater management agencies.

Our partnership was initially cemented in a 2001 agreement to form the Southern California Stormwater Monitoring Coalition, a regional collaboration of stormwater management agencies and regulators where SCCWRP plays a leading research role. Within a few years, four of the region's largest stormwater agencies joined SCCWRP as member agencies.

The strength of SCCWRP's stormwater partnerships has fundamentally reshaped the organization, transforming SCCWRP from a research entity that primarily focused on ocean issues associated with wastewater management into a more diversified, comprehensive water-quality research institute inclusive of both freshwater and marine ecosystems.

These changes didn't happen by chance: They're the direct result of visionary planning and leadership by the SCCWRP Commission.

In the 1990s, as SCCWRP research increasingly focused on studying land-based runoff to the coastal ocean, our governing board astutely recognized that the strength of SCCWRP lay not just in the science we do, but in the meaningful dialogue and interaction that we foster among diverse sectors of Southern California's water-quality management community – both regulators and regulated parties. Without the stormwater agencies at the table, the conversation about how our science should inform water-quality management was incomplete.

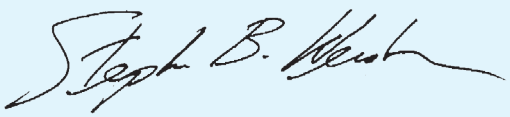
The Commission's ambitious vision for SCCWRP was memorialized during a seminal 2001 strategic planning retreat, when the Commission called on SCCWRP to reposition itself to study water quality throughout coastal watersheds. As we tackled more expansive, integrated research questions, we became empowered to help managers make more impactful, science-based decisions.

Looking back, the year 2001 truly was the start of seismic shift for both SCCWRP and stormwater managers. This year's Annual Report reflects on these first two decades of scientific progress and accomplishments.

As we do with all our work, SCCWRP approaches stormwater research by asking three overarching questions: (1) What is the extent of the problem, and how is it changing over time? (2) Where is the problem coming from? and (3) What can we do about it?

We've used this thought progression to organize the feature articles on the pages that follow. We start with an introductory overview article, followed by three articles that focus on each of the three overarching questions. The first article chronicles how we helped develop a regional monitoring program – based on biology – to quantify the nature and extent of problems in inland waterways. The second article chronicles our contributions to source-identification techniques that help address where problems originate, with an emphasis on microbial source tracking – one of the first projects conducted through the Stormwater Monitoring Coalition. The third article describes our newest major research area – stormwater best management practices (BMPs) – a solutions-focused area of study intended to help managers select the most appropriate ways to address identified problems.

I hope you enjoy reading about the development of our stormwater research programs and the evolution of our relationship with our stormwater management agencies.



Stephen B. Weisberg, Ph.D.
Executive Director

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ORIGINS AND EVOLUTION OF STORMWATER MANAGEMENT

In a span of two decades, Southern California has transformed its approach to managing runoff and protecting the health of inland waterways

At the outset of the modern environmental movement in the 1960s and 1970s, the health of inland waterways wasn't particularly high on the priority list of Southern California's water-quality management community.

California's Porter-Cologne Water Quality Control Act of 1969 and its federal counterpart, the Clean Water Act of 1972, focused managers' attention squarely on the industrial and wastewater discharges that were responsible for the lion's share of water-quality impacts to coastal ecosystems.

Throughout the 1970s and 1980s, Southern California water-quality managers invested in significantly upgrading treatment of wastewater prior to its discharge, and the most egregious chemical contaminants were banned from production and use. Coastal wildlife – from sea lions to brown pelicans – saw their populations rebound. Fish were no longer found with tumors and fin rot.

At the same time, these seminal management actions did not solve all coastal water-quality issues. To the contrary,

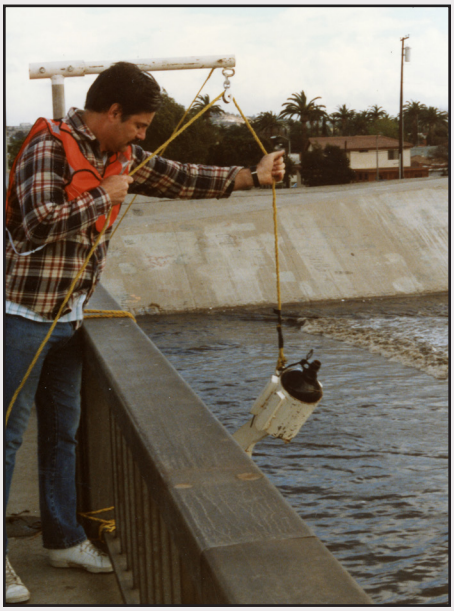
reversing many of the most alarming, 1960s-era environmental impacts brought into focus the next biggest contributor to pollution in Southern California's coastal ocean: land-based runoff.

Indeed, the runoff that travels through Southern California's vast network of rivers, creeks and stormwater conveyance systems carries with it pollution from across thousands of square miles of urban and agricultural landscapes – chemical contaminants, excess nutrients, toxins from freshwater algal blooms, fecal pathogens, and microplastics and other trash.

Historically, much of this runoff has been discharged – untreated – into the coastal zone. And unlike wastewater effluent and industrial discharges, these discharges are diffuse, voluminous during wet weather, and largely impractical to send to wastewater plants for treatment.

Throughout the 1980s and 1990s, SCCWRP played a key role in documenting the levels and types of contaminants found in Southern California runoff. This foundational work laid bare the enormity of the challenge of runoff contamination – and also set the stage for state and federal agencies to develop incrementally tougher, more prescriptive regulations for managing runoff.

A field crew from the Southern California Stormwater Monitoring Coalition reviews stream assessment protocols at Medea Creek in the Santa Monica Mountains. Southern California's stormwater management community is working toward solutions for protecting inland waterways from ecological degradation.



Henry Schafer, a SCCWRP scientist for 16 years, collects stormwater samples in 1990. SCCWRP has played a key role in documenting the levels and types of contaminants found in Southern California runoff.

The regulatory frameworks that drive stormwater management today began to take shape in 1987, when the Clean Water Act was amended to explicitly regulate stormwater discharges under the National Pollution Discharge Elimination System (NPDES) regulatory permitting program.

Within a few years, municipalities across Southern California and beyond responded by broadening the mandate of their public works departments, which historically were charged with preventing flooding and erosion.

Instead of just getting runoff safely and efficiently off the land and into the coastal ocean, these agencies also effectively became responsible for improving runoff water quality, including the runoff that gets discharged into Southern California's 4,300 miles of perennially flowing inland waterways.

The stormwater management community's new, dual mandate transformed the field in the 1990s – and paved the way for development of an ambitious, multi-faceted stormwater research agenda.

In Southern California, SCCWRP and other researchers led the region's nascent stormwater community in pooling their resources and working together to gain the upper hand on this complex management challenge.

In 2001, SCCWRP helped found the Southern California Stormwater Monitoring Coalition (SMC), a research and monitoring collaboration of major Southern California stormwater management agencies working toward solutions for improving and protecting runoff water quality.

The SMC initially focused on helping managers develop robust, coordinated programs to monitor runoff water quality. Today, it brings together 15 leading stormwater management agencies to collaborate on a broad, regionally focused project portfolio that includes everything from managing fecal contamination to optimizing stormwater control measures known as BMPs (best management practices).

Four of the region's largest stormwater management agencies also became part of Southern California's broader water-quality management community in the mid-2000s by joining SCCWRP as member agencies. Their membership in SCCWRP underscored their commitment to not just more effectively managing runoff in Southern California, but also becoming partners in holistically tackling the region's water-quality management challenges.

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Today, stormwater management in Southern California encompasses much

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Road to regulation: Origins of regulatory frameworks for stormwater management

Stormwater management is driven by federal regulatory frameworks that lay out prescriptive requirements and goals for protecting and improving runoff water quality. Although the federal Clean Water Act has been in place since 1972, these regulatory frameworks evolved over a nearly three-decade time span, from 1972 to 1999. The evolution of these frameworks encompasses two distinct eras.

Early approaches to stormwater regulation

Modern frameworks for stormwater regulation

1972

The Clean Water Act establishes a novel strategy for protecting aquatic health that focuses on regulating discharges into waterways.

The U.S. Environmental Protection Agency responds by establishing the National Pollution Discharge Elimination System (NPDES) permitting program.

The NPDES permitting program, however, initially focuses on industrial and wastewater discharges – not runoff.

Stormwater discharges, which can come from thousands of discrete sources, are initially considered impractical to regulate the same way as industrial and wastewater discharges.

1977

A landmark federal court case, National Resources Defense Council v. Costle, clarifies that the EPA must regulate stormwater discharges under the NPDES program.

In response, the EPA issues an initial generation of NPDES stormwater discharge permits.

Considered relatively lax by today's standards, these early permits contain few monitoring requirements and lack explicit regulatory thresholds to limit pollution levels in discharges.

1987

Convinced that the first 15 years of stormwater regulations have been inadequate to protect waterways, Congress makes pivotal amendments to the Clean Water Act that fundamentally alter how the EPA regulates stormwater discharges.

In response to the 1987 legislation, the EPA creates the foundation for the regulatory frameworks that drive stormwater management to this day – prescriptive monitoring requirements, effluent limitations, and TMDLs (total maximum daily loads) to enforce limits on pollution levels.

Because of the size and scope of the new regulatory paradigm, the EPA rolls out its updated stormwater permitting program in two phases.

Phase I, introduced in 1990, focuses on larger contributors to pollution in stormwater, including large municipalities and major construction projects.

Phase II, unveiled in 1999, brings smaller municipalities and other smaller dischargers under the same regulatory paradigm.

1990s

Municipalities in Southern California and beyond significantly expand and reshape their existing stormwater management programs – which traditionally focused on flood control and water conservation – to comply with their new stormwater discharge permits.

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Road to collaboration: Unifying Southern California's stormwater management community

To comply with new federal regulatory frameworks for stormwater management, Southern California municipalities made significant investments in their stormwater programs in the 1990s. As this nascent community grew, SCCWRP helped stormwater managers unify and work together through two key avenues.

Establishment of the SMC

Integration with SCCWRP

2001

The Southern California Stormwater Monitoring Coalition (SMC) is established to collaboratively address regional management challenges.

Ten agencies form the SMC in direct response to the 1990s rollout of modern regulatory frameworks for stormwater management.

Stormwater discharger permittees

- County of Los Angeles
- County of Orange
- County of Riverside
- County of San Diego
- County of San Bernardino
- County of Ventura
- City of Long Beach

California Regional Water Quality Control Boards

- Los Angeles
- San Diego
- Santa Ana

SCCWRP helps build the SMC's research agenda.

2003

Stormwater agencies begin joining SCCWRP, officially as associate member agencies, to strengthen their partnerships with the region's broader water-quality management community.

- County of Ventura, 2003-
- County of Los Angeles, 2004-
- County of Orange, 2005-
- County of San Diego, 2006-

- The County-level agencies indirectly represent a much bigger group of municipalities that serve as their stormwater discharge co-permittees.
- SCCWRP becomes better-positioned to more holistically tackle regional water-quality challenges.

2006

Three additional agencies join the SMC.

- City of Los Angeles
- State Water Resources Control Board
- Caltrans

The City of San Diego and U.S. EPA Office of Research and Development (collaborating organization) subsequently join, bringing the SMC to its present size of 16 members.

2010s

As a result of stormwater agencies' membership, SCCWRP increasingly shifts from solely documenting the region's runoff challenges to also studying how to effectively control and treat runoff.

Following years of planning, SCCWRP establishes a major thematic research area in 2019 centered around optimizing stormwater BMPs – a top priority for stormwater managers.

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more than just protecting the marine environment from contaminants that flow through inland waterways to the coastal ocean.

Through multiple regulatory programs, the region's stormwater managers also have become responsible for protecting the ecological integrity of the rivers, creeks and streams through which this runoff passes.

Is stormwater management a misnomer?

Southern California stormwater managers are responsible for much more than just managing the runoff generated by storm events. All water that reaches rivers, creeks and coastal marine waters via pipes, ditches, gutters and other conveyances is considered runoff that can be managed under regulatory frameworks for stormwater discharges. Consequently, both dry- and wet-weather runoff are major focuses of stormwater management in semi-arid Southern California.

They are obligated to mitigate, offset and prevent the physical, hydrological and environmental changes to these waterways – changes that can alter the natural flow patterns of these systems, disrupt and destroy sensitive plant and animal communities, as well as increase risks of erosion and flooding.

Simultaneously, stormwater managers are tasked with developing approaches that enable more runoff to be converted from an underutilized discharge product into a precious natural resource.

"Today, stormwater management is really somewhat of a misnomer, because it's evolved to encompass so much more than just stormwater, including water resource management," said Gerhardt Hubner, SMC Administrator and Executive Director of the California Stormwater Authority. "What stormwater managers do in Southern California is protect the ecological integrity of inland waterways, as well as the aesthetic, recreational, water supply enhancement, and cultural opportunities they provide to Southern California's diverse communities."

As stormwater management has evolved and matured over the past two decades, SCCWRP has played a key advisory and facilitation role in helping managers build a common vision and a shared set of values, goals and priorities for optimally protecting runoff water quality and the health of aquatic ecosystems.

SCCWRP has built a common technical foundation for Southern California stormwater management that has enabled researchers to collaborate closely with managers to conceptualize, develop and execute a coordinated, regionally focused research and monitoring agenda.

These seminal stormwater investments, in turn, have spurred development of a diverse array of management tools, programs and strategies that have helped Southern California make incremental progress toward its long-term water-quality improvement goals.

On the pages that follow are three articles that highlight key areas where scientific progress and accomplishments led by SCCWRP have helped the region's stormwater managers better protect runoff water quality and the health of aquatic ecosystems.

To improve and protect runoff water quality, Southern California's stormwater management community needs to know the answers to three fundamental management questions. For the past two decades, SCCWRP has been working to bring incremental insights and answers to all three questions, aligning its own research agenda to meet the needs and priorities of stormwater managers.

1 KEY MANAGEMENT QUESTION

» How is the ecological health of waterways impacted by runoff?

SCCWRP led the development of – and continues to facilitate – a regional stream monitoring program for coastal Southern California that has provided unprecedented, comprehensive insights into overall ecological health of inland waterways – and also paved the way for pursuing other types of leveraged regional investigations. **Page 10**

2 KEY MANAGEMENT QUESTION

» What are the origins of the major sources of pollution in runoff?

SCCWRP has been working for the past two decades to develop source-identification methods and tools for tracking major pollutants that degrade the health of inland waterways. In particular, SCCRWP has made significant advances in managers' ability to track fecal contamination to specific upstream points of origin. **Page 16**

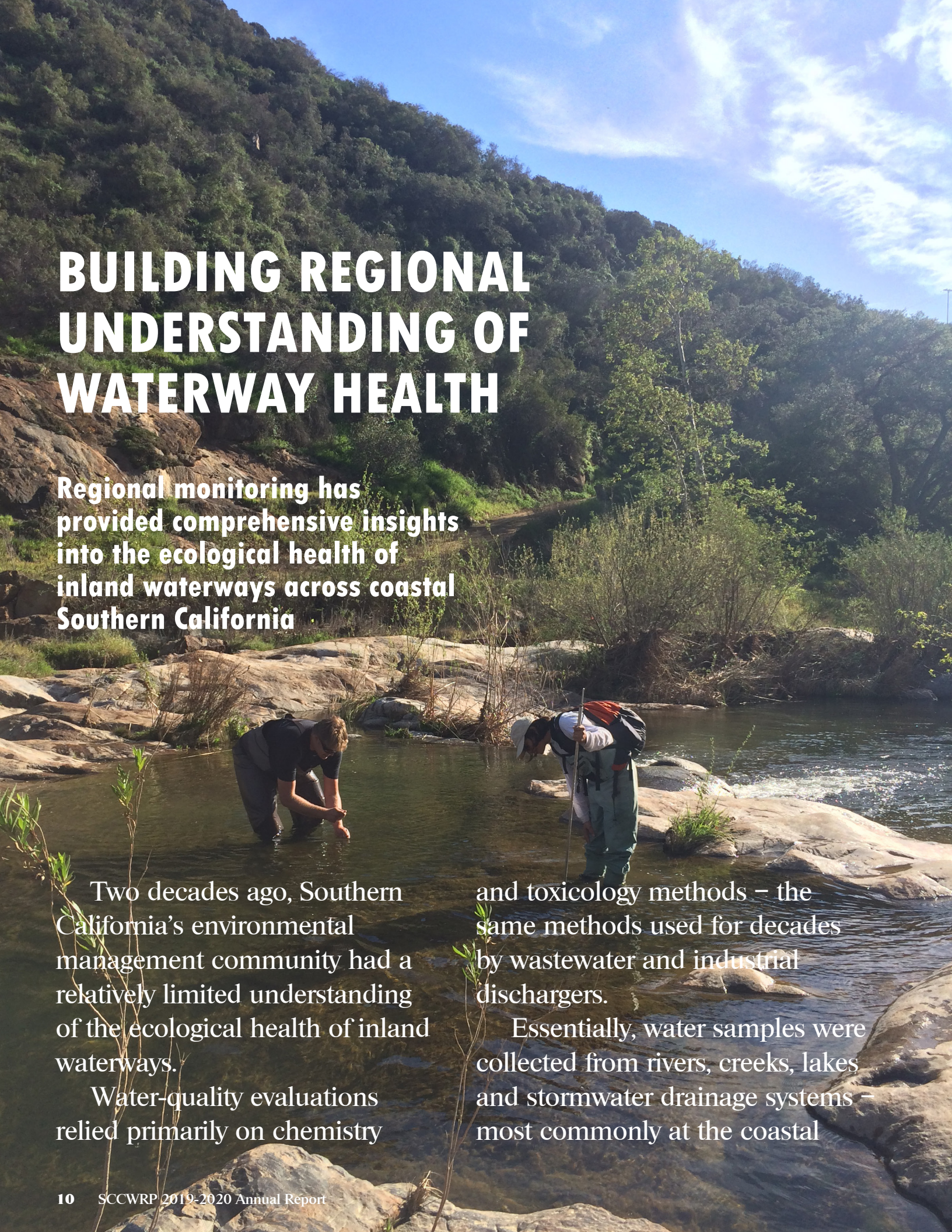
3 KEY MANAGEMENT QUESTION

» What specific solutions can be implemented to optimally improve and protect runoff water quality?

SCCWRP has been building a scientific foundation – monitoring strategies, tools and R&D programs – to help managers optimize the effectiveness of stormwater BMPs for reducing contamination in runoff. **Page 23**

BUILDING REGIONAL UNDERSTANDING OF WATERWAY HEALTH

Regional monitoring has provided comprehensive insights into the ecological health of inland waterways across coastal Southern California



Two decades ago, Southern California's environmental management community had a relatively limited understanding of the ecological health of inland waterways.

Water-quality evaluations relied primarily on chemistry and toxicology methods – the same methods used for decades by wastewater and industrial dischargers.

Essentially, water samples were collected from rivers, creeks, lakes and stormwater drainage systems – most commonly at the coastal

terminus – and then analyzed. Chemistry analysis methods were used to evaluate the levels and types of contaminants, and toxicology analyses were used to determine if these discharges harmed aquatic life.

Southern California environmental managers used these established methods to zero in on some of the most harmful chemical contaminants in industrial and wastewater discharges, including the pesticide DDT, which was banned in 1972, and a ubiquitous class of industrial chemicals known as PCBs, banned in 1976.

But inland waterways that drain to Southern California's coastal ocean are impacted by a much broader, interrelated array of environmental stresses stemming from the region's intensive urban and agricultural development. In addition to a wide variety of chemical contaminants ranging from trace metals to vehicle combustion products, these waterways are impacted by excess nutrients, changes to natural water flow patterns, alterations to adjacent landscapes, and other stresses.

Throughout the 1990s and early 2000s, as SCCWRP and other researchers documented these impacts, it became increasingly clear to Southern California's nascent stormwater management community that existing chemistry and toxicology analysis methods were inadequate to monitor the health of inland waterways. A new approach was needed.

"Stream ecosystems are impacted by much more than just the sum of the chemical contaminants that run through them," said Dr. Peter Ode, Laboratory Program Supervisor for the California Department of Fish and Wildlife. "What stormwater managers really needed was an integrator – a line of evidence that could provide insights about the cumulative impacts of all these different stressors on the stream ecosystem as a whole."

Over the past two decades, SCCWRP has played a leading role in helping Southern California's stormwater management community build a common scientific foundation upon which to reshape and expand how the ecological health of inland waterways gets monitored.

Significantly, SCCWRP introduced the stormwater management community to evaluating waterways by monitoring biological health – a foundational approach that has overcome the shortcomings of older monitoring methods.

Photos courtesy of U.S. Fish and Wildlife Service

The arroyo toad, left, and the arroyo chub and Santa Ana sucker, right, are among the freshwater species in Southern California vulnerable to the environmental stresses caused by intensive urban and agricultural development. The Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program is one of the key ways that stormwater managers examine how environmental stresses are affecting aquatic life across the region.

The signature manifestation of this shift to biology-based monitoring is the Southern California Stormwater Monitoring Coalition (SMC) Regional Watershed Monitoring Program, a coordinated monitoring effort launched in 2009 that relies heavily on biological assessment – or bioassessment – of organisms that live in waterways to capture high-quality, regional snapshots of ecosystem health.

SMC regional monitoring, which runs in five-year cycles, collects comparable, statistically representative data from across 4,300 miles of waterways representing 15 major watershed areas that drain to Southern California's coastal ocean.

Not only has SCCWRP-facilitated SMC regional stream monitoring helped stormwater managers understand at a regional scale which areas are most ecologically degraded and at greatest ecological risk, but the program also has paved the way for researchers to add on other types of leveraged investigations – everything from documenting the spread of trash pollution in waterways to measuring sediment accumulation in streambeds.

"The seminal investments in regional stream monitoring have had wide-ranging, extraordinarily positive impacts on stormwater management across Southern California," said Grant Sharp, Manager for the South OC Watershed Management Area at Orange County Public Works. "Much of our long-term, strategic planning and prioritization is guided and shaped by the insights provided by SMC regional monitoring."

Why a new monitoring paradigm was needed

A key impetus for SMC regional monitoring was the shortcomings of Southern California's existing monitoring paradigm for inland waterways.

Traditional chemistry- and toxicology-based monitoring methods are primarily sensitive to chemical contaminants – trace metals, pesticides, vehicle combustion products and so forth – which have the potential to be acutely toxic to aquatic organisms.

Thus, these monitoring methods are not designed to detect the much broader, more diverse set of environmental stresses that can impact biological communities in inland waterways, including:

» **Flow alterations**: Sensitive plant and animal communities that depend on predictable patterns in the flow of water for survival can be altered by human-induced disruptions to natural flows. These changes can occur as a result of alterations to the physical shape of stream channels, changes to the substrate in stream channel bottoms, and changes to surrounding landscapes.

» **Water temperature changes**: Changes in water temperature – induced by factors such as loss of shading and rising atmospheric temperatures – can threaten the survival of vulnerable aquatic life.

A SCCWRP field crew uses a kick net to collect samples of aquatic insects and other benthic invertebrates from a streambed. Biology-based monitoring of inland waterways enables environmental managers to directly measure how sensitive aquatic organisms respond to all of the stresses in their environment.

» **Physical habitat destruction**: A wide variety of human activities – everything from development projects to livestock operations – can alter and damage the habitats of sensitive plant and animal communities.

» **Excess nutrients**: Fertilizers and other nutrient-laden substances, which introduce excess nutrients to waterways as they wash off the land, can trigger overgrowth of algal matter, disrupting ecosystem health.

» **Bioactive contaminants**: Biologically active chemical contaminants that are found in a variety of pharmaceutical and personal-care products can interfere with growth, development and reproduction in aquatic life. Because these adverse effects aren't necessarily lethal, traditional toxicology analyses aren't calibrated to detect them.

To comprehensively monitor inland waterway health, a third line of evidence – biology – is needed.

Unlike chemistry and toxicology-based monitoring, biology-based monitoring directly measures how aquatic organisms that depend on waterways for survival respond to all of the stresses in their environment over time.

At the time that SCCWRP began exploring how to incorporate biology-based tools into stream monitoring in the early 2000s, biology-based monitoring was not a new concept.

SCCWRP and its member agencies successfully incorporated biology-based monitoring into the 1994 pilot of the Southern California Bight Regional Monitoring Program, a cyclical marine monitoring program that later served as the template for the SMC's regional monitoring program.

Through the Bight program, the biological condition of organisms that live in and on seafloor sediment is used as one of three core lines of evidence – along with chemistry and toxicology – for assessing the quality of coastal seafloor sediment.

As with sediment-dwelling organisms, certain biological communities in inland waterways play a key role in assessing overall ecological health.

In fact, when SCCWRP began working with the SMC to conceptualize the SMC Regional Watershed Monitoring Program in the mid-2000s, participants agreed that bioassessment should serve as the centerpiece line of evidence for tracking the health of aquatic life.

"The concept of monitoring the condition of in-stream biological communities was such an important addition to the regional stream monitoring program for Southern California," said Chris Crompton, Manager for the North OC Watershed Management Area at Orange County Public Works. "We realized that we could measure ecological impacts directly, rather than indirectly. At the same time, it introduced a whole new set of questions on how to use this information."

Learning how to monitor biological health

The basic premise behind using biology to monitor stream health is simple: Pollution and other human-induced environmental changes tend to impact sensitive aquatic organisms in predictable ways, triggering changes to the numbers and types of species present. Some species that are unaffected by the changes will flourish, while other species will decline.

For generations, scientists have recognized that certain aquatic species – especially algae and bottom-dwelling invertebrates – serve as particularly reliable indicators of human-induced stresses.

The challenge of monitoring these

Courtesy of Joseph Slusark Jr.

Insects and other benthic invertebrates collected from a streambed are sorted and counted under a microscope. Pollution and other human-induced environmental changes influence the makeup of certain stream biological communities in predictable ways, providing environmental managers with reliable tools for assessing overall ecological health.

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organisms in Southern California, however, is that inland waterways span thousands of square miles of varied landscapes and vastly different environmental conditions.

In other words, the biological community found in one part of Southern California might look very different from the biological community in another part – even in the absence of environmental stresses.

Cascading brooks in the rugged, snow-capped mountains of the San Gabriels, for example, support wholly different biological communities than meandering rivers in the semi-arid coastal basins. The makeup of these biological communities also can vary dramatically by season.

As a result of Southern California's continental-scale environmental variability, biology-based monitoring two decades ago was not a viable option for stormwater managers: Even if managers collected and analyzed the numbers and types of aquatic organisms in streams, they would have had no way to draw statistically meaningful conclusions about overall ecological health.

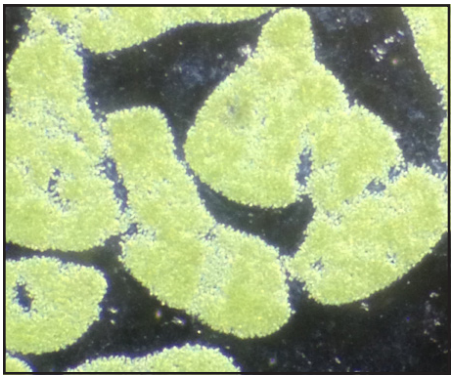
But beginning in the early 2000s, scientists began making significant advances toward helping stormwater managers increasingly make sense out of their field-collected biology data.

The first breakthrough was the development of a biology-based scoring tool known as the Southern California Coastal Index of Biotic Integrity (SoCal IBI), which combines multiple types of bioassessment metrics to help managers distinguish stream sites that are healthy from those that are ecologically degraded.

The tool, which was revolutionary for its time, provided a standardized process by which stormwater managers could compare their field-collected biological data to established information about what the biological community at the site should look like in the absence of human-induced environmental stresses. Variations of the SoCal IBI also were developed for use in other parts of California.

These regional tools evaluated differences between "expected" biological condition and actual "observed" biological condition, ultimately generating an overall numerical score reflecting the ecological health of the stream site.

At the same time, because the SoCal IBI was calibrated for use in just one part of the state, stream condition scores in Southern California were not directly comparable to those from other parts of the state, limiting managers' ability to contextualize the health of coastal Southern California streams in relation to the state as a whole.

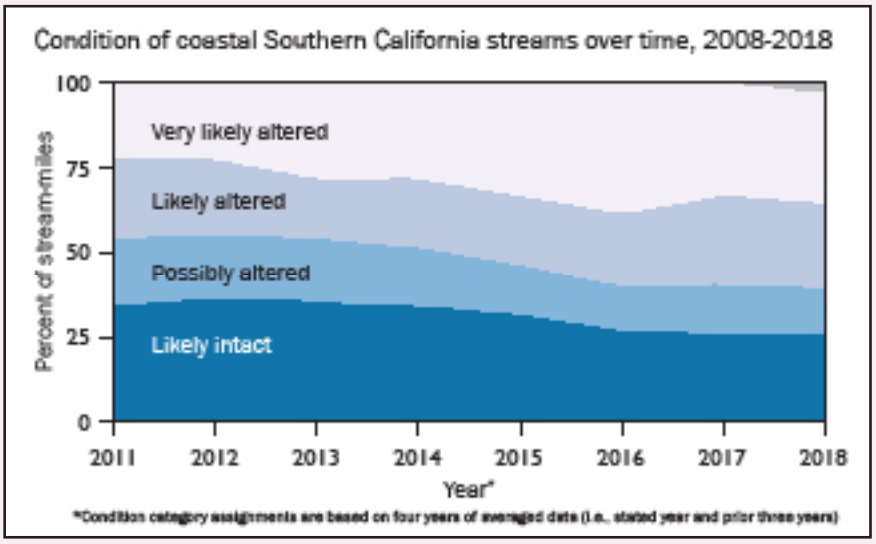


Benthic invertebrates like the larval dragonfly, left, and stream algae, right, are particularly reliable indicators of human-induced environmental changes to the ecological health of streams. The makeup of these communities changes in predictable ways in response to stress.

What SMC monitoring reveals about stream health

The first decade of SMC regional stream monitoring found that the overall health of coastal Southern California's 4,300 miles of perennially flowing streams is neither improving nor declining.

- About 25% of stream-miles were classified as "likely intact" biologically from 2008 to 2018.
- The top three stressors mostly likely responsible for biological degradation of streams were nutrients, major ions and degraded habitat.
- Other common stressors on streams – metals, toxicity and water-column pyrethroids – were likely limited or weakly associated with biological degradation.



About 25% of stream-miles in coastal Southern California remained "likely intact" biologically from 2008 to 2018, according to an SMC analysis of the first decade of bioassessment monitoring data.

"With the regional IBIs, we couldn't tell if Southern California streams were worse or better off than elsewhere," said Shuka Rastegarpour, an Environmental Scientist for the California State Water Resources Control Board. "This is essential information to understand when it comes to making decisions about how to prioritize and allocate our limited resources."

Putting biology-based insights into statewide context

The inherent shortcoming of California's first-generation, biology-based monitoring tools is that stream bioassessment scores could not be placed on a single linear scale.

Instead, tools like the SoCal IBI relied on a limited set of reference sites – typically in undeveloped mountainous regions – to represent the "expected" biological condition of all streams in the region.

Because each region used its own set of reference sites, Southern California stormwater managers could not be sure that "expected" biological condition was calibrated the same as in other parts of the state.

Comparing "expected" to "observed"

The multiple biology-based tools that have been developed in recent years for scoring stream health evaluate the "expected" biological condition of a site in relation to the actual "observed" biological condition of the site:

- The "expected" condition is generated via statistical predictive models.
- The "observed" condition is generated through field-collected data.

The ecological condition scores that are generated with these tools are presented on a linear scale – meaning that scores are directly comparable across Southern California and beyond, even for streams that are in very different environmental settings.

Streams like Morrison Creek in Northern California, above, that have been modified through channel hardening may not be able to achieve the same level of biological health as less modified channels. SCCWRP is analyzing biology-based stream monitoring data from across California to better understand how channel modification can influence biological health.

To work around this limitation, researchers recognized that they would need to amass bioassessment data from hundreds of reference sites all across the state, then take advantage of advances in statistical modeling to predict what the "expected" biological condition should be for almost any perennially flowing stream site statewide.

In Southern California, the SMC's nascent regional monitoring program – launched in 2009 – provided an invaluable platform for collecting the large number of high-quality, comparable bioassessment data points that researchers needed.

Then, SCCWRP and its partners used the SMC monitoring data – along comparable regional monitoring data from other parts of the state – to develop a pair of biology-based scoring tools that use statistical modeling to calculate "expected" biological condition at stream sites across California.

The California Condition Stream Index, which was completed in 2015, and the Algal Stream Condition Index, released a few years later, use the makeup of the benthic invertebrate community and algae community, respectively, to score the biological health of stream sites across California.

The key advantage of these tools is that "expected" biological condition can be estimated at the stream sites of managers' choosing, enabling these tools to be applied where they're needed most.

In addition, SCCWRP and its partners used the same powerful statistical modeling technique to develop the Index of Physical Habitat Integrity, which scores the physical habitat condition of Southern California's perennial flowing streams based on observable physical characteristics of the waterway channel and its riparian zone.

In recent years, these tools for scoring stream health have been adopted for routine use in monitoring programs, providing multiple, biology-based lines of evidence for evaluating ecosystem health – not just in Southern California, but statewide.

SCCWRP, meanwhile, is using the same basic statistical modeling technique to explore development of comparable, biology-based scoring tools for monitoring the health of Southern California streams that do not flow year-round.

"SMC regional monitoring has become more than just this program for monitoring stream health in Southern California," said Chad Loflen, Senior Environmental Scientist for the San Diego Regional Water Quality Control Board. "We've also extensively leveraged it to build better bioassessment tools – and now those

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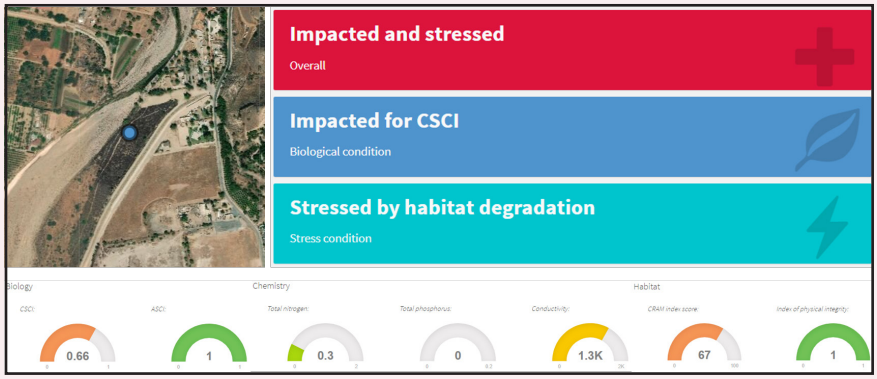
Integrating multiple lines of evidence

Biology-based monitoring isn't the only line of evidence that stormwater managers consider when evaluating ecosystem health. To help managers appropriately weigh multiple types of monitoring data, SCCWRP worked with the SMC to develop the Stream Quality Index scoring tool in 2019. The tool synthesizes three lines of evidence – biology, water chemistry and physical habitat – to assign stream sites to one of four condition categories reflecting the site's overall ecological health. The Stream Quality Index already has been incorporated into routine stream monitoring programs across Southern California.



Multiple types of monitoring data that go into the Stream Quality Index scoring tool can be visualized on an interactive, SCCWRP-developed web tool, above, which can display stream condition data for a single site of interest. Stream managers use the tool to draw inferences about potential causes of impacts and to prioritize sites for follow-up.

bioassessment tools are getting plugged right back into our management programs to protect streams in good condition, as well as identify and prioritize restoration actions at streams that need improvement."

Leveraging SMC regional monitoring

Like other SCCWRP-led regional monitoring programs, SMC regional monitoring is not limited to biology-based monitoring at a fixed set of sites using a fixed set of monitoring tools.

To the contrary, Southern California stormwater managers have used the program to pursue multiple other types of leveraged investigations that have shed additional insights into watershed health.

Other investigations that the SMC has undertaken or plans to undertake with its regional monitoring platform include:

» Documenting the spread of trash pollution through watersheds and its fate in the coastal zone

» Tracking hydrological changes to the natural flow patterns of streams to understand impacts to ecosystem health

» Creating regional maps of streams with different flow durations, ranging from perennially flowing to intermittently flowing, to better understand Southern California's network of waterways

» Tracking human fecal contamination upstream through waterways to investigate its points of origin

» Measuring the effectiveness of stormwater control measures known as BMPs (best management practices) in treating and removing contamination from runoff

Moreover, the core, biology-focused program is continuing to evolve as Southern California stormwater managers adapt the monitoring design to study additional facets of stream health and specific areas of management interest.

Among the ongoing investigations is an SMC effort to better understand how biological health is impacted in stream channels that have been lined with concrete, rocks and other armoring modifications. These types of streams may not be able to achieve the same level of biological health as less modified channels.

"We have come so far with regional monitoring for streams in just two decades, and the most exciting part is we're just getting started," said Gerhardt Hubner, SMC Administrator and Executive Director of the California Stormwater Authority. "The regional monitoring program the SMC has built is going to keep paying dividends for years to come as we keep gaining more and more insights from monitoring."

A field crew counts and classifies trash particles in the Los Angeles River as part of an effort to document the spread of trash pollution through waterways. Regional monitoring initiatives like the SMC's Regional Watershed Monitoring Program provide an invaluable platform for conducting leveraged investigations.

INVESTIGATING ORIGINS OF CONTAMINATION

Advances in source identification are enabling managers to pinpoint major sources of pollutants responsible for degrading water quality – especially fecal contamination

For generations, Southern California's environmental management community has effectively tracked the environmental effects of wastewater and industrial discharges through routine monitoring.

By zeroing in on the discrete locations where these "point" sources of pollution are introduced to aquatic environments, environmental managers have been able to prevent, mitigate and control a range of potential adverse consequences for downstream ecosystems.

Stormwater management, however, is the polar opposite paradigm: As water drains off the land, it transports contaminants from across thousands of square miles – metals, pesticides, grease and oil, bioactive contaminants, nutrients, trash, and so on.

By the time these diffuse, "non-point" sources of runoff pollution reach waterways, stormwater managers struggle to identify what portions of which pollution types originated at which specific upstream locations – or even if the contamination originated in runoff in the first place.

To methodically reduce and eliminate major pollution sources in runoff, stormwater managers turn to a suite of strategies, methods and tools collectively referred to as source identification.

In Southern California, advances in source identification have largely centered around estimating what levels and types of contaminants can be expected to run off the land based on how the land is being used – whether for residential, commercial, industrial, agricultural or some combination thereof.

Instead of trying to follow individual pollution signals upstream to specific individual origin points, researchers have developed a set of mathematical equations that can estimate overall contamination loading from a given area, enabling Southern California to rapidly gain a big-picture sense of how different areas are contributing to runoff pollution.

This land use-based strategy for reducing contamination in runoff – which SCCWRP adapted for use in Southern California

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in the mid-2000s – has become a foundational component of stormwater management over the past two decades.

Not only do contaminant loading estimates help stormwater managers pinpoint specifically where runoff contamination challenges are most significant, but the Southern California-specific mathematical equations used to generate these estimates also have been codified in a wide array of regulatory and other programs aimed at improving runoff water quality.

At the same time, contamination loading estimates based on land-use type aren't the only approach used by Southern California stormwater managers to investigate the origins of contamination in runoff.

For one specific type of contamination in runoff – fecal contamination – SCCWRP and other researchers have had an opportunity to push the source-identification envelope further – much further.

By far one of the most vexing contaminants found in Southern California runoff, fecal contamination is ubiquitous in Southern California in wet weather, regardless of how the land has been developed. And it is almost always above allowable levels, even in the region's most pristine upstream areas.

At the turn of the last century, source-identification technologies did not exist to identify where this fecal contamination was coming from, nor to understand what health risks, if any, the contamination posed to beachgoers in downstream coastal environments.

But over the past two decades, SCCWRP has led the region's stormwater management community in advancing source-identification technologies for fecal pollution – seminal advances that have made Southern California a global leader in confronting this vexing management challenge.

Already, stormwater managers have been using these source-identification advances to distinguish whether fecal contamination is originating from humans or dogs or birds or some other type of animal.

Meanwhile, researchers are continuing to pursue methods for more precisely and confidently pinpointing the origins of human sources – by far the most worrisome form of fecal contamination.

While scientists don't have all the answers yet to the origins of Southern

Causal assessment: A next-generation approach to source identification

Source-identification investigations encompass a broad range of management approaches for identifying sources of stress on waterways. One highly specialized form of source identification is causal assessment, a strategy for methodically identifying the most likely major sources of ecological degradation of aquatic environments.

Unlike other types of source-identification investigations that simply focus on pinpointing where major sources of contamination are originating, the central question guiding causal-assessment investigations is to understand which stressors among a universe of possible stressors are most likely responsible for degradation of the aquatic life that depend on waterways for survival.

Over the past decade, SCCWRP has helped advance the science of causal assessment for streams and other water bodies across California.

SCCWRP has developed a multi-tiered causal assessment framework to help managers systematically, rapidly and effectively narrow down likely causes of degraded ecological condition in Southern California's perennially flowing streams. Eventually, similar frameworks will be developed for other aquatic environments.

These scientific frameworks are a far cry from the months- to years-long, contentious processes that traditionally are associated with determining the causes of ecological degradation.

A key advantage of modern, rapid causal assessment is that it can help Southern California stormwater managers consider a broader, more encompassing universe of stressors that could be responsible for ecological degradation in waterways – beyond just contaminants in water – including flow alterations and aspects of physical habitat like substrate and water temperature.

The Southern California Stormwater Monitoring Coalition's Regional Watershed Monitoring Program has played an instrumental role in developing these causal assessment tools, generating many of the key data sets used to develop and calibrate the causal assessment tools.

In the coming years, researchers hope to build web-based tools that – within a couple of mouse clicks – can provide a definitive list of the biggest stressors most likely responsible for degrading a stream site's biological health.

A researcher collects field data on the condition of a stream in San Bernardino County's Big Bear Lake area. SCCWRP is developing causal assessment tools to help stormwater managers rapidly narrow down likely causes of degraded ecological condition.

Runoff pours out of a storm drain that terminates at a Southern California beach. Because runoff can transport fecal contaminants to the coastal zone, stormwater managers rely on science to help identify the specific upstream origins of fecal contamination.

California's widespread fecal contamination, continued scientific progress is incrementally providing managers with more insights. Moreover, these answers are coming with the high degree of confidence and precision that managers need to make potentially costly decisions to protect human health.

"Southern California beaches are among the most well-known and heavily used beaches in the world," said Neil Searing, Land Use/Environmental Planner III for the County of San Diego Watershed Protection Program. "And at every step of the way, science has unlocked our ability to investigate where fecal contamination in our waterways could be coming from. Best of all, we're getting closer to definitive, region-wide answers to one of the most difficult, pressing challenges we face as stormwater managers."

Combating fecal contamination at beaches

Fecal contamination at Southern California beaches has been a top management priority – and a top management challenge – for generations.

As early as the 1950s, Southern California's wastewater treatment agencies recognized that releasing primary-treated effluent through coastal outfalls near the shoreline had the potential to contaminate beach water to unsafe levels. They responded by extending the length of wastewater outfalls so that treated effluent could be discharged farther from shore.

As the modern environmental movement got underway in the 1960s and 1970s, public pressure mounted to upgrade wastewater treatment processes. Wastewater treatment agencies responded by upgrading most of the region's wastewater treatment agencies to full secondary treatment, effectively eliminating effluent as a chronic source of fecal contamination in coastal beach water.

Then, in 1997, California passed a law – Assembly Bill 411 – requiring water quality at public beaches to be monitored weekly for fecal indicator bacteria during the popular beachgoing months. Within a few years, the environmental advocacy organization Heal the Bay began using all of the new bacterial data to calculate letter grades for Southern California beaches, which put a spotlight on lingering hotspots of coastal fecal contamination.

The more that environmental managers tracked fecal contamination levels at beaches, the more apparent it became that runoff was a major contributor.

A 1995 epidemiology study of swimmers in Santa Monica Bay, for example, found that beachgoers who swim near flowing storm drains are 50% more likely to get sick than swimmers just 400 yards away.

A few years later, Southern California's environmental management community captured the first regional snapshot of coastal fecal contamination during the 1998 cycle of the Southern California Bight Regional Monitoring Program.

The Bight '98 study, which involved collecting more than 1,000 samples during both wet weather and dry weather, found that although 95% of Southern California beaches met bacterial standards in dry weather, the beaches that did not were almost exclusively near flowing storm drains.

Far more troubling, though, were the study's wet-weather findings, which showed that coastal fecal contamination soared across the region following rain storms. Runoff was widely seen as the primary culprit.

"Bight '98 was a real wake-up call – the problem was laid out in black and white," said Dr. Rachel Noble, a Distinguished Professor of Marine Sciences at the University of North Carolina, Chapel Hill and a former SCCWRP microbiologist. "But we couldn't do anything about it until we could figure out where all the fecal pollution in runoff was coming from."

Investigating sources of fecal contamination in runoff

One of the first strategies that Southern

Elevated fecal contamination levels at beaches – common during wet weather in Southern California – can trigger public health officials to post warning signs advising beachgoers to stay out of the water.

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California stormwater managers pursued to investigate the origins of wet-weather fecal contamination was figuring out what types of animals contribute to the pollution – cows, horses, birds, dogs, humans and so on.

Understanding which animals are major contributors is important because it paves the way for stormwater managers to better direct their limited resources toward reducing the biggest sources first.

For example, when Los Angeles County managers hypothesized that the majority of fecal contamination in water at a beach was coming from birds, they installed an aerial network of crisscrossing wiring over the beach to discourage birds from frequenting the area. Similarly, Orange County managers hired falconers and posted coyote signs.

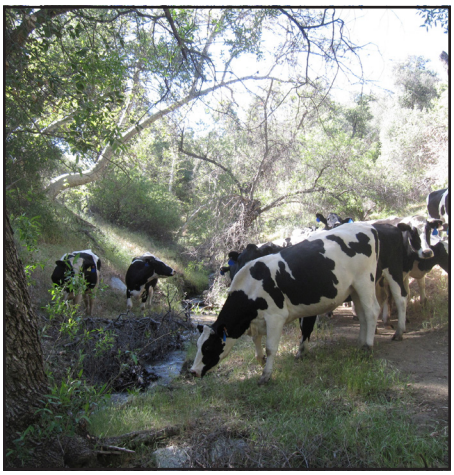
In the early 2000s, as stormwater managers initially pursued animal-specific source-identification technologies for fecal contamination, they discovered that multiple methods were already in use – some described in peer-reviewed literature, but most still experimental and investigator-specific.

These nascent, unproven methodologies were unable to provide source-identification insights with the confidence that managers needed.

Moreover, Southern California's environmental management community was still required to use a tried-and-true, bacteria culture-based method for monitoring fecal contamination in coastal beach waters, even as this method can only quantify the total amount of bacterial contamination in aquatic environments – from all sources combined, including human.

Courtesy of Port of Los Angeles

Metal cables that have been suspended in a grid pattern over the heads of beachgoers at Inner Cabrillo Beach in Los Angeles County are designed to deter birds from defecating in the area. Southern California stormwater managers rely on source-identification technology to determine which types of animals are major sources of fecal pollution in runoff.



Livestock grazing near streams is one of many activities that can introduce fecal contamination to waterways. Knowing which animals are major sources of fecal pollution enables environmental managers to direct limited resources toward reducing the biggest sources first.

Given that none of the animal-specific source-identification methods had been subjected to rigorous, independent testing, SCCWRP in 2001 began working with Southern California's stormwater management community to develop a national method comparison study to figure out which methods worked best.

The landmark study, published in 2003, found that most of the emerging source-identification methods could not reliably distinguish among fecal sources from different animals, including humans.

At the same time, the study found that one method – a DNA-based method that focuses on a type of fecal bacteria known as *Bacteroides dorei* that grows in digestive systems – offers a consistently effective way to distinguish among different animal sources.

In response, stormwater managers across Southern California and beyond terminated their use of the other experimental source-identification methods – and instead rallied around developing and optimizing DNA-based fecal source-identification methods for multiple types of priority animals.

Today, this approach to source identification is known as microbial source tracking (MST). It consists of a widely used set of methods – officially known as non-library-based molecular MST methods – that have been vetted for numerous priority animals, including birds and dogs.

"Source-identification methods for identifying fecal contamination by animal type have become a foundational tool that stormwater managers can use to help pinpoint major sources of fecal contamination in runoff," said Dr. Alexandria Boehm, Professor of Civil and Environmental Engineering at Stanford University.

Focusing on human sources of fecal contamination

As useful as fecal source-identification methods for various animals have become, one animal has risen above all others for its management significance – humans.

The type of fecal pollution at greatest risk of sickening humans, human

fecal contamination has emerged as a top priority for Southern California's stormwater management community.

Moreover, the methods that have been developed for identifying human contamination in aquatic environments have become SCCWRP's most impactful contribution to the MST field. Indeed, advances in this arena have put SCCWRP at the global forefront of fecal source-identification R&D for the past two decades.

The first significant breakthrough dates back to the early 2000s, as SCCWRP and its partners were vetting various methods for identifying feces by animal type. Researchers at Oregon State University who participated in the 2003 method comparison study discovered that a specific human genetic marker on the *Bacteroides* gene – known as HF183 – offers a particularly reliable way to identify human sources in fecal contamination.

Over the next several years, SCCWRP and its partners worked to refine the HF183 method and to validate its ability to reliably distinguish human from non-human fecal contamination. SCCWRP also developed methods to detect and reliably quantify HF183 levels in runoff.

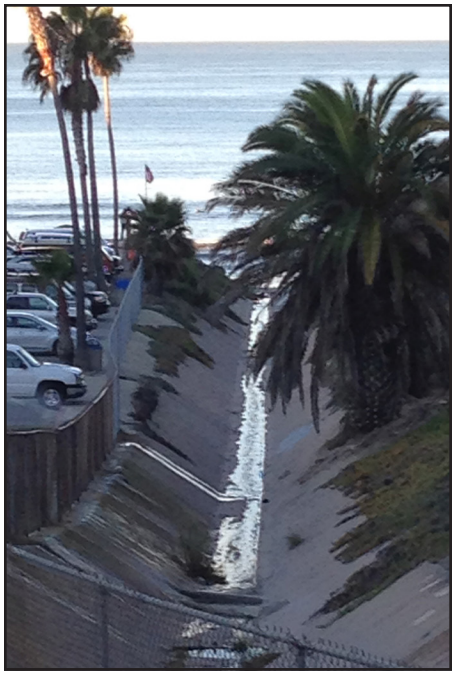
Southern California environmental managers, meanwhile, began using HF183 to track fecal contamination in the coastal ocean in wet weather.

During the 2013 cycle of the Southern California Bight Regional Monitoring Program, researchers quantified HF183 levels at the mouths of nearly two dozen Southern California watersheds that terminate at the coastline. The study found that HF183 was ubiquitous in runoff, even as the HF183 measurements did not necessarily correlate well with existing beach fecal indicator bacteria data collected via traditional monitoring methods.

Not only was the study a wake-up call that the fecal contamination in waterways carried a human signature, but it also fundamentally shifted stormwater managers' approach to remedying Southern California's fecal contamination problem.

Instead of focusing primarily on reducing total fecal contamination levels, managers recognized that – at least in the short term – their limited resources might be better spent trying to eliminate human-specific hotspots of fecal contamination.

"As a result of the development of HF183, we suddenly had this powerful source-identification tool that showed us that fecal contamination in wet-weather runoff has a human signature," said Grant Sharp, Manager for the South OC Watershed Management Area at Orange County Public Works. "The question switched from 'Are there human sources in runoff?' to 'Which human sources are in runoff?'"



Storm drain channels like the one that terminates at San Diego's Tourmaline Surfing Park, above, can introduce fecal contamination to coastal beach water. SCCWRP is working to identify specifically where these fecal pollution sources are originating upstream.

Surfers paddle away from shore at San Diego's Ocean Beach shortly after a storm. SCCWRP is at the global forefront of efforts to determine the origins of fecal contamination with improved specificity and reliability, so that environmental managers can better protect beachgoers from water-borne pathogens.

Considering potential sources of human fecal pollution

Human fecal contamination is as ubiquitous in Southern California waterways as it is difficult to track back to a specific upstream source.

Although Southern California stormwater managers are aware of individual instances of contamination – accidental sewage spills, illegal dumping, illicit sewer connections to storm drains and so forth – the incidents that managers know about cannot fully explain the pervasive, consistent levels of human fecal contamination during wet weather.

Thus, researchers hypothesize that the fecal contamination must be coming from one or more sources that environmental managers don't yet have the tools and/or monitoring programs to reliably identify. Potential sources that could be evading

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Courtesy of Orange County Sanitation District

Dr. Samuel Choi of the Orange County Sanitation District, foreground, works with Jessica Roussos to analyze water samples for fecal contamination using a qPCR (quantitative polymerase chain reaction) instrument. The DNA-based technology helps environmental managers confirm if fecal contamination has a human signature.

detection in heavily populated Southern California include:

» Sanitation infrastructure – either private or public sewer systems, or both – that could be overflowing during wet weather as a result of suddenly inundation with storm water

» Small leaks from underground sanitary systems – either private or public sewer systems, or both – that are exfiltrating during wet weather and that are not detectable using existing sewer inspection methods

» Private lateral lines that connect to public sewer systems that could be malfunctioning and/or that could have been illegally connected to storm drains

» Septic systems that could be leaking or malfunctioning

» Illegal dumping of raw sewage by owners of RVs and boats

» Individual inputs from people experiencing homelessness

Definitively identifying which of these sources is responsible is a top priority for stormwater managers, as each of these potential sources would likely require a different set of strategies and tools to effectively control and manage.

For example, if private or public sanitation infrastructure is found to be a major contributor, managers would need to be able to pinpoint where specifically the leaks or other problems are with these systems.

Similarly, if the problem is primarily with privately maintained sanitation infrastructure, managers would need to pinpoint specific problematic systems – and hold the appropriate owners accountable.

Meanwhile, if individuals are illegally dumping raw sewage, managers would need to pinpoint when and where these incidents are occurring.

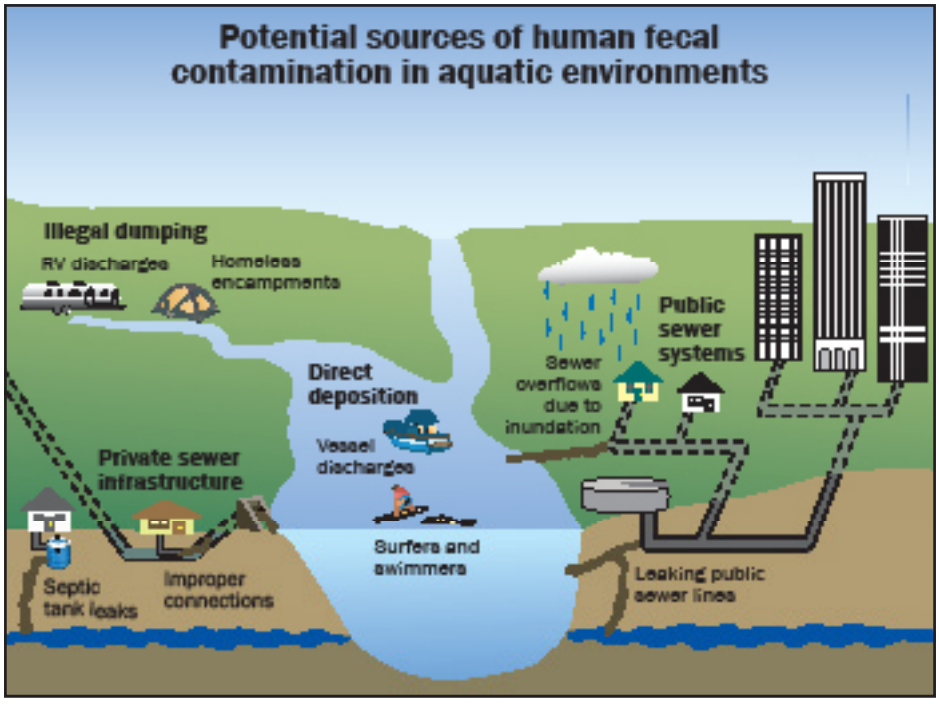
Furthermore, managers need to do more than just rule each potential source out or in. They need certainty from source-identification investigations, as the management interventions that could be required have the potential to be costly, protracted and contentious.

"Tracking fecal contamination may seem like trying to find a needle in a haystack – there are so many potential places where it could be originating," said Dr. Patricia Holden, Professor of Environmental Microbiology at the University of California, Santa Barbara. "Yet the problem of combating Southern California's fecal contamination challenge is increasingly being tackled by being systematic in studying each of the possible sources."

Developing ways to distinguish among human sources

The technology does not yet exist to distinguish among the many potential human sources of fecal contamination in waterways.

But in recent years, researchers have been moving rapidly toward developing reliable methods for answering these questions.



In Southern California, SCCWRP and its partners have begun laying the groundwork to methodically document how much fecal matter might be getting illegally deposited in and near storm drains and waterways; this work will include comprehensive field surveys of human activities taking place near rivers and creeks.

In a parallel effort, SCCWRP also is investigating how to use a pair of experimental source-identification approaches – known as community fingerprinting and chemical fingerprinting, respectively – to determine whether fecal contamination in waterways could be coming from leaking or overflowing sanitation infrastructure. These efforts build off prior work by other researchers to identify distinct signatures in human contamination that can be traced back to municipal sewers.

With both of these complementary fingerprinting technologies, researchers are looking for unique overall genetic and chemical patterns, respectively, in contaminated water that can be linked back to multiple specific types of infrastructure, including publicly maintained sewer pipes and privately maintained septic tanks and lateral lines.

"With these fingerprinting approaches, we're trying to move away from relying on a single, custom-tailored molecular marker like HF183 for source tracking," said Jo Ann Weber, Water Resources Manager for the County of San Diego Watershed Protection Program. "HF183 has been revolutionary, but at the same time, it can't shed light on the specific origins of the human sources of contamination that it's detecting in the environment."

Using the fingerprinting approaches, SCCWRP is working to reliably detect differences in the genetic makeup of the microbial community that lives inside different types of infrastructure, as well as in the chemical makeup of the contents of different types of infrastructure, respectively. Then, researchers can look for these same genetic and chemical signatures, respectively, in downstream waterways.

In 2018, SCCWRP began pursuing exploratory, proof-of-concept studies to understand whether the genetic and chemical patterns are unique to different types of infrastructure. The results so far have been promising.

SCCWRP and its partners found that the microbial community that lives on the insides of sewer pipes – known as biofilm – is different from the biofilm community that lives inside storm drain pipes. These differences in genetic patterns have the potential to enable researchers to determine whether fecal contamination in a storm drain or waterway originated in sanitation infrastructure.

Similarly, researchers found that the contents of sewer pipes contain marquee chemical differences – known as non-targeted chemical fingerprints – that distinguish them from the contents of storm drain pipes.

A vacuum-powered sampling device is inserted through a manhole into an underground sewer system in San Diego County to collect water that has just been pumped through a roughly 300-foot-long section of pipe. SCCWRP and its partners are working to develop a novel field method for detecting potential leaks in specific segments of underground sewer pipes.

Long-term vision for identifying human fecal sources

If the fingerprinting studies continue to show promise, they could pave the way for developing reliable methods for linking fecal contamination in downstream waterways to upstream sanitation and/or stormwater infrastructure.

By using the two technologies in tandem, researchers might one day be able to track fecal contamination in runoff back to a specific neighborhood – or even a specific section of sewer or storm drain pipe.

In parallel with this exploratory work, SCCWRP also is developing a novel field method for detecting small leaks in specific sections of underground sanitation pipes. Initial, proof-of-concept results from the leak detection method indicate that it has the potential to detect even very small leaks in sewer pipes.

Researchers' long-term vision is to be able to use the two fingerprinting technologies to help pinpoint the specific origin points of fecal contamination in waterways, then to use the leak detection method to pinpoint specific sections of pipes that could be responsible.

"The past two decades of source identification work on fecal contamination exemplify both the vexing challenges associated with source identification work," said Dr. Shelley Luce, President and Chief Executive Officer for Heal the Bay, "and also the important scientific breakthroughs that have moved water-quality managers incrementally closer toward solving this persistent challenge."


Courtesy of Los Angeles County Department of Public Works

OPTIMIZING BMP SOLUTIONS FOR POLLUTION REMOVAL

Improved understanding of stormwater control measures is helping to reduce runoff contamination

Stormwater management is more advanced and more encompassing in Southern California than almost anywhere else in the nation.

From routine street-sweeping to public education to source-control strategies that target major contamination sources, Southern California has aggressively pursued an integrated, multi-pronged strategy for reducing contamination in runoff.

Southern California's approach to runoff management is borne out of necessity: The region is deluged by infrequent but intense

storm events that trigger massive amounts of water to wash off thousands of square miles of urban and agricultural landscapes.

This runoff carries a wide range of contaminants that historically have flowed – untreated – into Southern California's ecologically and economically important inland waterways and coastal waters.

With the rise of modern regulatory frameworks for stormwater management in the 1990s, it became apparent that Southern California would need many more solutions to gain the upper hand on its runoff pollution challenges – strategically placed, site-specific engineering solutions known as structural stormwater BMPs (best management practices).

Over the past two decades, Southern California managers have increasingly come to rely on this suite of engineered solutions to improve runoff water quality.

Unique in that they typically control and treat runoff near where the runoff originates, structural stormwater BMPs encompass everything from bioretention systems that remove runoff contaminants, to underground infiltration galleries that keep runoff out of storm drain systems.

Runoff from a parking lot drains to a bioretention system containing special engineered soil media designed to remove contaminants. Strategically placed stormwater BMPs like bioretention systems can be installed near where runoff originates, reducing the volumes of runoff and contaminants entering storm drain systems.

These systems typically use a combination of capture, infiltration, diversion, detention, retention and flow-through technologies to manage runoff.

Already, Southern California has spent billions of dollars constructing thousands of structural stormwater BMPs across the region. And the region is making long-term plans to spend billions more in the coming decades to meet water-quality improvement targets for runoff.

"Structural BMPs – appropriately designed and maintained – have become the foundational stormwater management strategy over the past two decades in protecting and improving runoff water quality," said Dr. Xavier Swamikannu, Assistant Adjunct Professor of Environmental Science and Engineering at the University of California, Los Angeles and former Chief of Storm Water Programs for the Los Angeles Regional Water Quality Control Board.

As the pace of BMP implementation has accelerated across Southern California, SCCWRP and other researchers have partnered with stormwater managers to diagnose what's working – and what's not – with existing structural stormwater BMPs.

SCCWRP has spent the past two decades conducting research and building monitoring programs to provide a rigorous technical foundation for improving the performance of stormwater BMPs regionwide.

This technical foundation is informing

Two main types of stormwater BMPs

Structural stormwater BMPs that are implemented by public agencies are generally custom-designed, constructed and maintained for each site where they're placed. They fall into two main categories:

» **Flow-through BMPs** treat and remove contaminants as runoff flows through them. Multiple flow-through BMPs are often implemented together as a "treatment train."

» **Infiltration BMPs** capture runoff and allow it to soak gradually into the ground, preventing the runoff – and associated contaminants – from being discharged into aquatic ecosystems.

Courtesy of Riverside County Flood Control and Water Conservation District

Bioretention systems like this one, above, under construction in Riverside County use special engineered soil media to remove contaminants as runoff passes through.

Courtesy of Los Angeles County Department of Public Works

Infiltration galleries like this underground one, above, under construction in Los Angeles County are designed to collect and store runoff from nearby neighborhoods, enabling the runoff to soak into the ground.

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Courtesy of Orange County Public Works

An Orange County Public Works field crew installs pervious pavers in a parking lot, enabling rainfall to soak into the ground instead of running off into storm drains. SCCWRP has been working to better understand how different types of stormwater BMPs perform.

key decisions about how stormwater managers design, construct, monitor and maintain all of the BMPs that will be implemented at strategic locations across Southern California in the coming decades.

"It's important to not only optimize the performance of individual BMPs, but to implement BMPs effectively throughout the watershed, increasing water quality for the region while demonstrating good stewardship of public funds," said Dr. Melissa Turcotte, Head Environmental Engineering Specialist for the Los Angeles County Department of Public Works.

From flood-control solutions to water-quality solutions

The engineering design principles upon which structural stormwater BMPs are based have been around for decades.

In fact, long before structural BMPs were used to treat runoff water quality in Southern California, they served as solutions for preventing and mitigating flooding.

As the region rapidly urbanized over the past century, Southern California flood-control managers implemented a wide variety of structural BMPs to help transport water as efficiently and rapidly as possible off the land.

These legacy drainage features – dams, retention ponds, impound basins, and concrete lining along rivers and streams – are hallmarks of Southern California's flood-control infrastructure, and largely remain in place to this day.

The purpose of the flood-control BMPs in these systems was – and still is – to help control sudden deluges of stormwater that, a century ago, routinely threatened property and human life across Southern California. Indeed, updated versions of flood- and erosion-control BMPs continue to be routinely integrated into development and redevelopment projects across Southern California.

At the same time, the rise of modern regulatory frameworks for stormwater management in the 1990s caused flood-control managers to begin fundamentally rethinking the role of structural BMPs.

Instead of just flood-control solutions, water resources engineers and planners increasingly have come to see the value of using these costly public-engineering investments to provide a broad range of societal benefits – including improving runoff water quality and protecting the ecological integrity of inland waterways.

This shift in management thinking was spurred in large part by a growing body of research by SCCWRP and others that showed that public education, street sweeping and other "non-structural" stormwater BMPs were typically inadequate on their own for achieving most water-quality improvement goals for runoff.

For example, in the mid-2000s, SCCWRP examined the role of non-structural BMPs in reducing contamination in runoff from residential neighborhoods. The study found that

Runoff pours out of a storm drain that terminates along the Southern California coast. Although some runoff can be diverted to wastewater treatment plants during dry weather, wet-weather runoff is too voluminous in coastal Southern California to be treated at central sites prior to discharge.

Sanitary sewer diversions

Not all structural stormwater BMPs have complex mechanistic inner workings. Among the earliest structural stormwater BMPs to be implemented in Southern California were simple diversions of runoff to wastewater treatment facilities.

This BMP solution is used primarily to stop contaminated runoff from reaching coastal areas, especially populated beaches. Introduced to Southern California in the 1990s, sanitary sewer diversions are limited in their scale and effectiveness. The challenge is that wastewater treatment facilities lack the capacity to treat all runoff in Southern California, especially during wet weather.

non-structural BMP solutions like public education only reduce runoff contaminants to a very limited extent.

"Non-structural BMPs play an important role in stormwater quality programs as we seek to better educate the public and businesses, and as we work on true source control to remove or reduce problem water-quality constituents from products of commerce, such as copper in vehicle brake pads," said Chris Crompton, Manager for the North OC Watershed Management Area at Orange County Public Works. "Structural solutions, though, remain a key tool for advancing water-quality improvement, and are required for compliance with stormwater permits."

Challenges of implementing BMPs in Southern California

Even as structural stormwater BMPs are seen as foundational to improving runoff water quality across Southern California, the region faces unique challenges with BMP implementation:

- Space to implement structural stormwater BMPs in Southern California's urban centers is extraordinarily limited. Managers typically use public land to implement BMPs, and look for ways to broaden the project's benefits to society, such as coupling BMP implementation with an upgrade to a public park.
- Southern California BMPs need to be able to treat runoff in extraordinarily compressed timeframes – typically after months of little or no use. The region's infrequent but intense rainfalls typically flush huge volumes of contaminants off the land at once, further intensifying the demand on BMPs.
- The BMP solutions that are shown to work in other parts of the country may not perform nearly as well in Southern California. Stormwater managers need to collect copious amounts of Southern California-specific monitoring data to evaluate performance effectiveness.

Optimizing structural BMPs to treat runoff

Structural stormwater BMPs represent perhaps Southern California's best chance to meaningfully improve runoff water quality across diverse, highly populated landscapes.

Unlike non-structural BMP solutions such as public education that indirectly promote contamination removal, structural stormwater BMPs are field-implemented solutions that directly treat contamination in runoff, typically near its points of origin.

This core advantage enables stormwater managers to adapt the design of structural stormwater BMPs to the specific settings where they're placed, including optimizing performance based on estimated runoff volumes and flow rates.

Modern structural stormwater BMPs often use complex, interdependent mechanisms and processes to remove contaminants in runoff, including settling, filtration, adsorption, evaporation, transformation and degradation.

These mechanisms must be engineered to work for a wide range of possible settings under highly dynamic, unpredictable operating conditions.

Consequently, the performance of more complex structural stormwater BMPs can be significantly influenced by multiple variables, including:

- the volumes of runoff that flow into the BMPs
- how water gets directed into structural BMPs and moves through these systems
- the levels and types of contamination in the runoff being treated
- the specific engineered soil media that some structural BMPs use to filter and transform contaminants
- local environmental conditions at the site

Over the past decade, stormwater managers have significantly expanded their R&D programs as they work to methodically tease apart these variables – and ultimately determine what changes and adjustments could be made to improve BMP performance.

SCCWRP has played a leading role in shaping this BMP-focused research agenda, helping stormwater managers to study a wide range of different variables and environmental conditions that influence the mechanistic performance of structural BMPs – both positively and negatively.

SCCWRP's goal is to incrementally provide best-practices guidance to help stormwater managers optimize routine

Dr. Nabiul Afrooz evaluates the capacity of engineered soil media to remove contaminants from runoff in a SCCWRP laboratory. The setup enables researchers to conduct more controlled, small-scale experiments prior to field-testing the media in bioretention systems.

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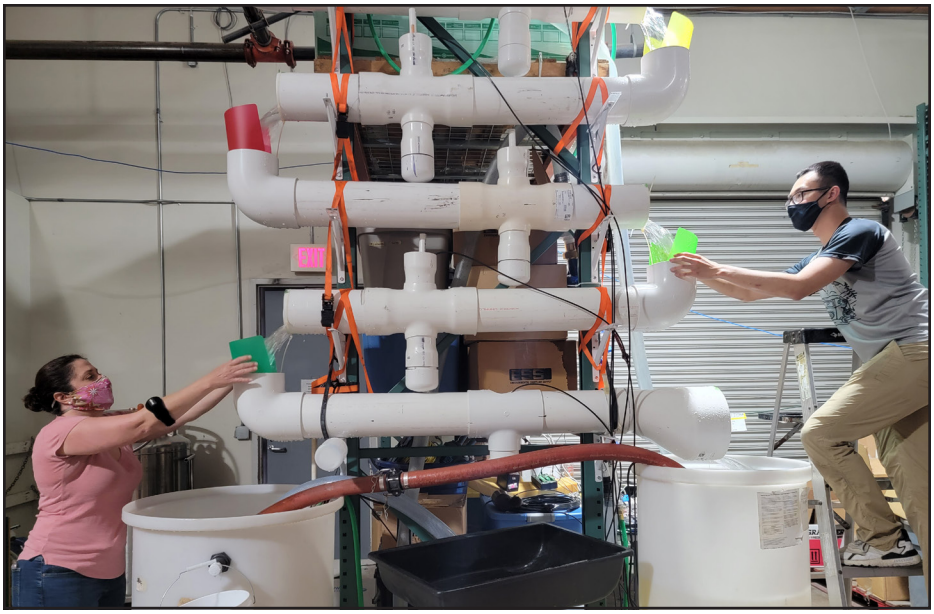

SCCWRP's Dr. Elizabeth Fassman-Beck, left, and Brandon Fong calibrate a custom-built flow-measurement system that will be deployed in the field to measure the volume and flow rate of runoff entering and exiting bioretention planters. Researchers are studying the mechanistic inner workings of bioretention planters and other stormwater BMPs to help optimize their performance.

maintenance for existing BMPs, which have useful lives that can span decades. Simultaneously, SCCWRP is developing insights to guide the placement, design and construction of future generations of structural BMPs.

"It's critical that we understand the mechanistic inner workings of BMPs," said Dr. Nabiul Afrooz, Water Resource Control Engineer for the California State Water Resources Control Board. "Better mechanistic understanding can greatly inform BMP selection and design to tackle a specific contaminant or a set of contaminants in runoff. These insights can also help managers revisit existing BMPs and explore what alterations and changes could be made to improve their performance."

Integrating BMP placement decisions into planning

Southern California stormwater managers have increasingly come to rely on BMPs as a cornerstone strategy for meeting long-term, regional water-quality improvement goals.

Indeed, structural stormwater BMPs have become a requirement in most development and redevelopment projects.

To make all-important decisions about how to design and situate BMPs for maximum effectiveness, watershed planners rely on mathematical modeling – essentially, a set of equations that predict how effective BMPs will be at removing contamination from runoff after they've been implemented at a specific location.

This modeling work requires two main types of data inputs: estimates of the levels and types of contaminants the BMPs can be expected to treat, and estimates of how effective the BMPs will be in treating these contaminants.

Over the past two decades, SCCWRP has produced groundbreaking research that has served as a foundation for stormwater managers to generate high-quality, comprehensive data sets.

First, in the early and mid-2000s, SCCWRP built the technical foundation for estimating what levels and types of contaminants can be expected to wash off Southern California's watersheds and sub-watersheds. The effort – which remains the most comprehensive runoff flow and contaminant wash-off data set ever produced for Southern California – required collecting data for hundreds of contaminant types across dozens of sites over a nearly five-year period.

From this data set, SCCWRP showed that watershed modeling parameters being used in other parts of the country were not applicable in Southern California – largely because of the region's unique rainfall and runoff patterns.

Then, SCCWRP developed a set of modeling parameters unique to Southern California that enable managers to estimate – based on land-use type, amount of rainfall and time elapsed since previous rainfall – the average concentrations of contaminants washing off the land, known as the event mean concentration (EMC).

Over the years, the set of pollutant build-up and wash-off coefficients that SCCWRP developed to calculate these estimates have served as the foundation for a number of long-term water-quality master planning efforts across Southern California – and today are essential in efforts to model the performance of BMPs yet to be implemented.

"The land-use EMCs are one of SCCWRP's most important contributions to the field of stormwater management in Southern California," said Dr. Elizabeth Fassman-Beck, Principal Engineer at SCCWRP. "This work has been so foundational in our ability to model watersheds for a variety of uses, including now as a critical input for BMP performance modeling."

Courtesy of Riverside County Flood Control and Water Conservation District

Runoff that has been treated by a bioretention planter is measured as it flows out of a white effluent pipe. Researchers are working to collect high-quality, comparable data sets on the performance effectiveness of stormwater BMPs across Southern California.

Runoff gradually flows through a bioswale along a roadway in Orange County. SCCWRP is working with the Southern California Stormwater Monitoring Coalition to build a regional monitoring network for collecting comparable, high-quality data on the effectiveness of BMPs in removing contaminants from runoff.

Challenges estimating BMP performance effectiveness

Although SCCWRP's watershed modeling work paved the way for Southern California stormwater managers to generate high-quality data on runoff flows and pollutant wash-off, managers' ability to model BMP performance relies on a second major type of data input: the estimated performance effectiveness of the BMPs that are being considered for implementation.

A present-day focal point for SCCWRP, the goal of this research area is to provide stormwater managers with high-quality, relevant data and analytical tools to quantify performance effectiveness of BMPs in Southern California.

Although performance data for a wide variety of structural BMPs are publicly available, including in an international online database, the challenge is that much of the data were generated by monitoring the performance of BMPs outside the region. Only a small fraction of the data is from Southern California.

However, structural BMPs can perform very differently in other parts of the country than in semi-arid Southern California, where the region's extended dry-weather periods provide ample opportunity for contaminants to accumulate on the landscape.

In 2019, SCCWRP vividly illustrated how this dearth of Southern California-specific BMP monitoring data has impacted managers' ability to model BMP performance across the region.

In unveiling the California BMP Effectiveness Calculator, which estimates the effectiveness of common flow-through BMPs in removing specific types of contaminants from runoff, researchers noted that the predictive capabilities of the calculator tool are constrained by the lack of Southern California-specific data.

"The quality of our watershed planning efforts around BMPs is only as good as the quality of the data that feed into our models," said David Laak, Stormwater Resources Manager for the Ventura County Public Works Agency. "Thus, it's the lack of access to relevant, Southern California-specific BMP performance data that is really propelling the current – and next – generation of stormwater BMP research."

Building capacity to estimate BMP performance effectiveness

In recent years, SCCWRP and other researchers have been working to amass high-quality data sets for BMP performance across Southern California.

These efforts culminated with a 2020 decision by the Southern California Stormwater Monitoring Coalition (SMC) to begin building a regional BMP monitoring network that will be capable of comprehensively and rapidly collecting comparable BMP performance data from across Southern California.

The SCCWRP-led initiative, which is expected to be operational by 2023, will use consistent, standardized methods for measuring and tracking the performance of a wide variety of structural BMPs.

The goal of the regional monitoring network is to collect a huge amount of BMP performance data rapidly, simultaneously and cost-effectively. Much like the SMC's annual stream bioassessment monitoring, the network will unify and build on existing, smaller BMP monitoring efforts developed by SMC member agencies – creating a unified, comparable data set reflecting the broad diversity of BMPs across Southern California.

The BMP performance analyses generated through the regional monitoring network will be used to inform not only long-term watershed planning efforts, but also managers' efforts to quantify which design parameters seem to be working best for multiple BMP types and locations under a variety of different conditions.

Additionally, stormwater managers will be able to evaluate the maintenance activities critical to supporting long-term treatment functions – and the conditions that compromise performance – for a variety of BMPs of different ages and maintenance protocols.

The regional monitoring network reflects SCCWRP's ongoing commitment to producing managerially actionable insights on BMP performance that lead to improved design, construction and maintenance of these water-quality improvement solutions.

"We have spent millions of dollars implementing BMPs in the region," said Paul Alva, Principal Engineer for the Los Angeles County Department of Public Works. "Providing optimal operations and maintenance ensures that these regional projects are improving water quality throughout the life span of the project while providing community benefits. We cannot afford a margin of uncertainty in terms of a project's performance effectiveness."

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Accomplishments

SCCWRP is a national leader in aquatic sciences research, with a comprehensive research agenda that spans a diverse array of water-quality issues confronting the environmental management community.

SCCWRP mission

To enhance the scientific foundation for management of Southern California's ocean and coastal watersheds

Research themes

SCCWRP's research agenda is organized around eight major thematic areas

73 Number of peer-reviewed journal articles and book chapters co-authored by SCCWRP that appear in this Annual Report

31 Number of technical reports co-authored by SCCWRP that appear in this Annual Report

150 Number of leadership roles that SCCWRP scientists hold with professional societies, advisory committees and editorial boards of scientific journals **Page 79**

Bioassessment

As environmental managers increasingly turn to measuring the health of aquatic systems through biological assessments – or bioassessment – SCCWRP is developing next-generation approaches that use benthic invertebrates, algae and other organisms to evaluate ecological condition across a variety of environments, from streams to the coastal ocean.

Ecohydrology

As environmental managers work to protect aquatic systems and the biological communities they support from human-induced alterations to hydrological flow patterns, SCCWRP is working to better understand these ecohydrological relationships and how to develop science-informed best management practices around them.

Regional Monitoring

To give environmental managers comprehensive, big-picture snapshots of the condition of aquatic systems and how they are changing over time, SCCWRP facilitates the design and execution of multi-agency regional monitoring – notably, the Southern California Bight Regional Monitoring Program and the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program.

Eutrophication

With anthropogenic nutrient inputs a leading cause of eutrophication – or accelerated accumulation of organic matter from over-growth of aquatic plants and algae – SCCWRP is working to help environmental managers understand the deleterious impacts of excessive nutrients and how they can more effectively manage nutrient loading to water bodies.

Stormwater BMPs

As stormwater BMPs (best management practices) are implemented to reduce contamination in wet- and dry-weather runoff, SCCWRP is building a technical foundation to help environmental managers optimize the long-term effectiveness of these stormwater control measures.

Climate Change

As environmental managers seek out next-generation solutions for mitigating and offsetting the local impacts of global carbon dioxide emissions, SCCWRP is developing strategies to optimally position vulnerable aquatic systems – and the biological communities they support – to cope with and adapt to climate change.

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 this microbial contamination, identify the source(s) of the contamination, and understand the risk of illness from water contact.

Contaminants of Emerging Concern

To help environmental managers identify which of the tens of thousands of largely unmonitored CECs in aquatic systems pose the greatest potential health risks to wildlife and humans, SCCWRP is developing novel approaches to rapidly and cost-effectively screen water bodies for CECs, connect screening-level monitoring data to higher-level biological responses, and understand exposure routes.

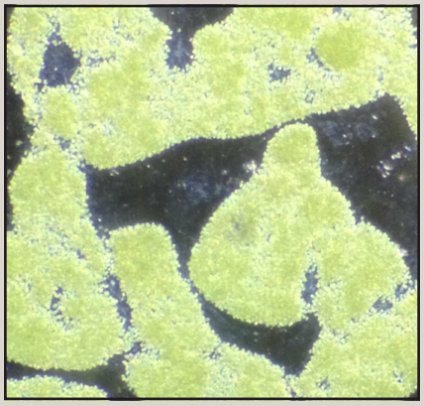
Tool developed to score stream health by evaluating algae

SCCWRP and its partners have developed a statewide scoring tool that uses the makeup of algal communities to evaluate the overall ecological health of wadeable streams, providing a complementary second line of evidence to another scoring tool that evaluates stream health using benthic macroinvertebrate communities.

The Algal Stream Condition Index (ASCI), described in a journal article published in 2020, uses the same predictive modeling approach pioneered by the California Stream Condition Index (CSCI), where reference conditions are modeled to determine what the makeup of biological communities should look like at a given site in the absence of human-induced environmental stressors.

Both the ASCI and CSCI, which was unveiled in 2015, were developed through extensive sampling efforts statewide. The ASCI leveraged more than 10 years of algal bioassessment data collected by multiple partners in wadeable streams across California.

The ASCI gives stream managers the option to evaluate stream diatom communities only, or both diatom communities and soft-bodied algae. This flexibility helps ensure the ASCI is broadly applicable.



Stream algae, as seen under a microscope, is a reliable indicator of the overall ecological health of wadeable streams. The Algal Stream Condition Index scoring tool that was co-developed by SCCWRP uses algae as the basis for evaluating the health of wadeable streams statewide.

Water-quality managers intend to use ASCI scores to report on the condition of streams statewide as part of a biennial Integrated Report to federal officials.

SCCWRP and its partners also are exploring how to develop a molecular version of the ASCI, where – instead of manually analyzing algae samples under a microscope – the DNA of the algae could be sequenced to determine the makeup of the algal community.

Ephemeral streams condition index being developed using local bioindicator data

SCCWRP and its partners have initiated an effort to build a management tool for scoring the health of ephemeral streams that will be modeled after similar tools developed for perennially flowing streams.

Researchers in 2019 began using biological indicator data collected from dry streams across Southern California to build and calibrate the tool, which will use the makeup of terrestrial arthropod, riparian arthropod and bryophyte communities as indicators of overall stream health.

The tool is being designed as a complement to the California Stream Condition Index and the Algal Stream Condition Index, which were co-developed by SCCWRP for use in perennial streams.

Ephemeral streams, or streams that flow only immediately after rain events, make up about 60% of all streams in Southern California.

SCCWRP's stream management partners have played a key role in generating the biological indicator data from sites across Southern California.

Framework developed for assessing health of seagrass beds

SCCWRP has developed a three-tiered framework incorporating bioassessment methods to help environmental managers across coastal California comprehensively evaluate the health of eelgrass and other types of submerged aquatic vegetation (SAV).

The SAV assessment framework, completed in 2020, represents an important step forward in efforts to better protect and restore this ecologically significant habitat, including within California's estuarine Marine Protected Areas (MPAs).

Seagrass beds – which are scattered across shallow coastal areas with soft-bottom sediments – provide critical habitat for organisms such as fish, crabs, lobsters and turtles. SAV condition assessments also can shed important insights into overall coastal water quality and ecological integrity.

The framework could be incorporated into routine seagrass monitoring programs, including California's estuarine MPA program.

Researchers have developed an assessment framework to help managers evaluate the health of seagrass beds like this one, above, in Newport Bay in Orange County. Seagrass beds are scattered across shallow coastal areas with soft-bottom sediments in California; they provide critical habitat for organisms such as fish, crabs, lobsters and turtles.

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Translational molecular ecology in practice: Linking DNA-based methods to actionable marine environmental management

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Abstract

Molecular-based approaches can provide timely biodiversity assessments, showing an immense potential to facilitate decision-making in marine environmental management. However, the uptake of molecular data into environmental policy remains minimal. Here, we showcase a selection of local to global scale studies applying molecular-based methodologies for environmental management at various stages of implementation. Drawing upon lessons learned from these case-studies, we provide a roadmap to facilitate applications of DNA-based methods to marine policies and to overcome the existing challenges. The main impediment identified is the need for standardized protocols to guarantee data comparison across spatial and temporal scales. Adoption of Translational Molecular Ecology–the sustained collaboration between molecular ecologists and stakeholders, will enhance consensus with regards to the objectives, methods, and outcomes of environmental management projects. Establishing a sustained dialogue among stakeholders is key to accelerating the adoption of molecular-based approaches for marine monitoring and assessment.

Citation

Aylagas, E., A. Borja, X. Pochon, A. Zaiko, N. Keeley, K. Bruce, P. Hong, G.M. Ruiz, E.D. Stein, S. Theroux, N. Geraldi, A. Ortega, L. Gajdzik, D.J. Coker, Y. Katan, T. Hikmawan, A. Saleem, S. Alamer, B.H. Jones, C.M. Duarte, J. Pearman, S. Carvalho. 2020. Translational Molecular Ecology in practice: Linking DNA-based methods to actionable marine environmental management. *Science of the Total Environment* DOI:10.1016/j.scitotenv.2020.140780.

SCCWRP Journal Article #1131
Full text available by request: pubrequest@sccwrp.org

Predictive biological indices for algae populations in diverse stream environments

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Abstract

Predictive biological indices have transformed the bioassessment landscape by allowing universal indices to be applicable across diverse environments. The successful development of a predictive benthic macroinvertebrate index for California wadeable streams helped to demonstrate the power of these tools in complex geographic settings. However, previous efforts to develop predictive algal indices for California were limited by poor performance and were ultimately unsuccessful. For this study, we leveraged a robust statewide dataset to develop two different types of predictive algal indices for California wadeable streams: an index of observed-to-expected taxa (O/E) to measure taxonomic completeness and a multimetric index (MMI) to evaluate ecological structure. We developed multiple versions of each index, including one for diatoms, one for soft-bodied algae, and a hybrid index using both assemblages. We evaluated index performance using a series of screening criteria for precision, accuracy, responsiveness, and regional bias. We found that final index performance varied among all assemblages: the best performing O/E index was a diatom-only index, whereas the predictive diatom and hybrid MMIs outperformed all other indices with excellent responsiveness and precision. We found that in comparison to benthic macroinvertebrates, algal communities were characterized by high beta diversity across reference sites and low average species richness per site, resulting in disparate algal populations that were challenging to model with predictive approaches, particularly for soft-bodied algae assemblages. While all O/E indices were considered to have weak performance, the predictive diatom and hybrid MMIs are accurate, responsive, and precise indices that will provide a powerful assessment of biological condition for statewide applications.

Citation

Theroux, S., R.D. Mazor, M.W. Beck, P.R. Ode, E.D. Stein, M. Sutula. 2020. Predictive biological indices for algae populations in diverse stream environments. *Ecological Indicators* DOI:10.1016/j.ecolind.2020.106421.

SCCWRP Journal Article #1135
Full text available online: www.sccwrp.org/publications

The Stream Quality Index: A multi-indicator tool for enhancing environmental management

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ABSTRACT

Assessment of stream health is a function of the physical, chemical, and biological integrity of the water body. While monitoring of all three indicator types is common, combining them into a unified assessment of stream quality is rare. In this study, a unified index was developed that compares biological response to physical and chemical stressors for southern California wadeable streams using a scientifically rigorous, easy-to-understand tool intended to facilitate stream management. The Stream Quality Index (SQI) is based on a stressor-response empirical model that quantifies the expected likelihood that chemical and physical stressors will impact multiple components of biological condition. While the individual stressor and response components are quantitative and have similar meaning across a variety of environmental settings, the final SQI narrative assessment is categorical and designed to be directly actionable within a management context. The four narrative assessment categories are: (1) "healthy and unstressed" (i.e., unimpacted biology, no stressors); (2) "healthy and resilient" (i.e., stressed, but biological communities are healthy); (3) "impacted and stressed" (i.e., impacted biology from observed stressors); and (4) "impacted by unknown stress" (i.e., biology is impacted, but stressors are low). To facilitate adoption by managers, a web-based application was developed that not only maps overall SQI results, but also enables users to readily access underlying quantitative information for stressors and biological responses. This transparent design was intended; high-level output and foundational components of the SQI are relevant for different audiences and details are not sacrificed for accessibility.

CITATION

Beck, M., R.D. Mazor, S. Theroux, K.C. Schiff. 2019. The Stream Quality Index: A multi-indicator tool for enhancing environmental management. *Environmental and Sustainability Indicators* DOI:10.1016/j.indic.2019.100004.

SCCWRP Journal Article #1091
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The importance of open science for biological assessment of aquatic environments

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ABSTRACT

Open science principles that seek to improve science can effectively bridge the gap between researchers and environmental managers. However, widespread adoption has yet to gain traction for the development and application of bioassessment products. At the core of this philosophy is the concept that research should be reproducible and transparent, in addition to having long-term value through effective data preservation and sharing. In this article, we review core open science concepts that have recently been adopted in the ecological sciences and emphasize how adoption can benefit the field of bioassessment for both prescriptive condition assessments and proactive applications that inform environmental management. An example from the state of California demonstrates effective adoption of open science principles through data stewardship, reproducible research, and engagement of stakeholders with multimedia applications. We also discuss technical, sociocultural, and institutional challenges for adopting open science, including practical approaches for overcoming these hurdles in bioassessment applications.

CITATION

Beck, M.W., C. O'Hara, J.S. Stewart-Lowndes, R.D. Mazor, S. Theroux, D.J. Gillett, B. Lane, G. Gearheart. 2020. The importance of open science for biological assessment of aquatic environments. *PeerJ* DOI:10.7717/peerj.9539.

SCCWRP Journal Article #1132
Full text available online: www.sccwrp.org/publications

Use of aquatic insects in bioassessment

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ABSTRACT

Bioassessment (also called biomonitoring) is the science and practice of using resident organisms to evaluate the environmental health of a waterbody (Rosenberg and Resh 1993; USEPA 2011). Because legislation in the United States, European Union, and Canada explicitly mandates assessment and maintenance of biological or ecological integrity (e.g., U.S. Clean Water Act, Canada Waters Act, the European Union

Water Framework Directive), the bioassessment process increasingly underpins management decisions and increases the value of monitoring programs in North America. Although bioassessment studies may address basic research questions, the connection to management sets them apart from other studies in the field of ecology: Bioassessment activities may take place at a range of spatial and temporal scales, from cellular assays to whole-ecosystem studies, although assemblage-level studies based on aquatic macroinvertebrates (along with fish and algae) are generally the most widely used and integrated into legislation or management programs. Bioassessment is now an essential element of the aquatic resource manager's toolkit because, unlike physical or chemical measures, biological data provide a direct indication of a water- body's ability to support aquatic life (Karr 1981; Rosenberg and Resh 1993; Kuehne et al. 2017). It is not a surrogate for water quality or habitat quality, but rather a direct measure of condition. Although this chapter focuses on freshwater bioassessments in North America (and mostly in streams, where they are routinely applied), examples and research from other parts of the world and in other habitat types are included.

Citation

Mazor, R.D., V.H. Resh, D.M. Rosenberg. 2019. Use of Aquatic Insects in Bioassesment. in: R.W. Merritt, K.W. Cummins, M.B. Berg (eds.), *An Introduction to the Aquatic Insects of North America* pp. 141-164. Kendall Hunt Publishing Company. Dubuque, IA.

SCCWRP Book Chapter #1094
Full text available online: www.sccwrp.org/publications

Prioritizing management goals for stream biological integrity within the developed landscape context

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Abstract

Stream management goals for biological integrity may be difficult to achieve in developed landscapes where channel modification and other factors constrain in-stream conditions. To evaluate potential constraints on biological integrity, we developed a statewide landscape model for California that estimates ranges of likely scores for a macroinvertebrate-based index that are typical at a site with the observed level of landscape alteration. This context can support prioritization decisions for stream management, like identifying reaches for restoration or enhanced protection based on how observed scores relate to model predictions. Median scores were accurately predicted by the model for all sites in California with bioassessment data (Pearson correlation r = 0.75 between observed and predicted for calibration data, r = 0.72 for validation). The model also predicted that 15% of streams statewide are constrained for biological integrity within their present developed landscape, particularly for urban and agricultural areas in the South Coast, Central Valley, and Bay Area regions. We worked with a local stakeholder group from the San Gabriel River watershed (Los Angeles County, California) to evaluate how the statewide model could support local management decisions. To achieve this purpose, we created an interactive application, the Stream Classification and Priority Explorer, that compares observed scores with predictions from the landscape model to assign priorities. We observed model predictions consistent with the land-use gradient from the upper to lower watershed, where potential limits to achieving biological integrity were more common in the heavily urbanized lower watershed. However, most of the sites in the lower watershed scored within their predicted ranges, and were therefore given a low priority for restoration. In contrast, 2 low-scoring sites in the undeveloped upper watershed were prioritized for causal assessment and possible future restoration, whereas 3 high-scoring sites were prioritized for protection. The availability of geospatial and bioassessment data at the national level suggests that these tools can easily be applied to inform management decisions at other locations where altered landscapes may limit biological integrity.

Citation

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Selecting comparator sites for ecological causal assessment based on expected biological similarity

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Abstract

Streams and other waterbodies in poor ecological condition often require causal assessment to determine appropriate follow-up actions. However, site-specific causal assessments can be time consuming. To streamline the process, we describe a quantitative method that expedites a key component of causal assessment: identifying a group of ecologically similar (comparator) sites with which to compare and contrast biological condition and stressor exposure at the site of interest. A good set of comparator sites should: 1)

represent environments that could support biota similar to the degraded site in the absence of disturbance, 2) comprise a gradient of biotic conditions, and 3) contain enough sites to assess variability. We used expected biological similarity to select good sets of comparator sites from a large pool of potential sites for 15 poor-condition test sites in Southern California. Expected biological similarity was measured as Bray–Curtis dissimilarity values (BC) calculated from the expected benthic macroinvertebrate taxa lists produced by a predictive biotic index of stream health. We used an expected BC threshold of ≤0.05 to create the sets of comparator sites. Based on this criterion, we identified >70 comparator sites for each of the 15 test sites. To illustrate their utility in a causal assessment, we used the comparator sites to derive evidence of whether 4 example stressors—elevated conductivity, elevated N, elevated fine sediment, and hardening of the stream channel—contributed to the poor biotic conditions at each of the 15 test sites. We used spatial-temporal co-occurrence type of evidence to evaluate the data and found that elevated conductivity and elevated fine sediment were the likely cause of biotic degradation at the most test sites. We developed the comparator site selection approach described here in the context of the stream bioassessment program in California, USA, but this approach could be adapted by any bioassessment program with a large amount of sample data and an associated predictive index of biotic condition, such as the National Aquatic Resource Survey. Furthermore, this approach lays the groundwork for rapid, screening-level causal assessment to become part of routine bioassessment, which would then inform follow-up management actions.

CITATION

Gillett, D.J., R.D. Mazor, S.B. Norton. 2019. Selecting comparator sites for ecological causal assessment based on expected biological similarity. *Freshwater Science* 38:554-565.

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Characterizing benthic macroinvertebrate and algal biological condition gradient models for California wadeable streams, USA

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ABSTRACT

The Biological Condition Gradient (BCG) is a conceptual model that describes changes in aquatic communities under increasing levels of anthropogenic stress. The BCG helps decision-makers connect narrative water quality goals (e.g., maintenance of natural structure and function) to quantitative measures of ecological condition by linking index thresholds based on statistical distributions (e.g., percentiles of reference distributions) to expert descriptions of changes in biological condition along disturbance gradients. As a result, the BCG may be more meaningful to managers and the public than indices alone. To develop a BCG model, biological response to stress is divided into 6 levels of condition, represented as changes in biological structure (abundance and diversity of pollution sensitive versus tolerant taxa) and function. We developed benthic macroinvertebrate (BMI) and algal BCG models for California perennial wadeable streams to support interpretation of percentiles of reference-based thresholds for bioassessment indices (i.e., the California Stream Condition Index [CSCI] for BMI and the Algal Stream Condition Index [ASCI] for diatoms and soft-bodied algae). Two panels (one of BMI ecologists and the other of algal ecologists) each calibrated a general BCG model to California wadeable streams by first assigning taxa to specific tolerance and sensitivity attributes, and then independently assigning test samples (264 BMI and 248 algae samples) to BCG Levels 1–6. Consensus on the assignments was developed within each assemblage panel using a modified Delphi method. Panels then developed detailed narratives of changes in BMI and algal taxa that correspond to the 6 BCG levels. Consensus among experts was high, with 81% and 82% expert agreement within 0.5 units of assigned BCG level for BMIs and algae, respectively. According to both BCG models, the 10th percentiles index scores at reference sites corresponded to a BCG Level 3, suggesting that this type of threshold would protect against moderate changes in structure and function while allowing loss of some sensitive taxa. The BCG provides a framework to interpret changes in aquatic biological condition along a gradient of stress. The resulting relationship between index scores and BCG levels and narratives can help decision-makers select thresholds and communicate how these values protect aquatic life use goals.

CITATION

Paul, M.J., B. Jessup, L.R. Brown, J.L. Carter, M. Cantonati, D.F. Charles, J. Gerritsen, D.B. Herbst, R. Stancheva, J. Howard, B. Isham, R. Lowe, R.D. Mazor, P.K. Mendex, P.R. Ode, A. O'Dowd, J. Olson, Y. Pan, A.C. Rehn, S. Spaulding, M. Sutula, S. Theroux. 2020. Characterizing benthic macroinvertebrate and algal biological condition gradient models for

California wadeable Streams, USA. *Ecological Indicators* DOI:10.1016/j.ecolind.2020.106618.

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Using co-occurrence network topology in assessing ecological stress in benthic macroinvertebrate communities

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Abstract

Ecological monitoring of streams has often focused on assessing the biotic integrity of individual benthic macroinvertebrate (BMI) communities through local measures of diversity, such as taxonomic or functional richness. However, as individual BMI communities are frequently linked by a variety of ecological processes at a regional scale, there is a need to assess biotic integrity of groups of communities at the scale of water- sheds. Using 4,619 sampled communities of streambed BMIs, we investigate this question using co-occurrence networks generated from groups of communities selected within California watersheds under different levels of stress due to upstream land use. Building on a number of arguments in theoretical ecology and network theory, we pro- pose a framework for the assessment of the biotic integrity of watershed-scale groupings of BMI communities using measures of their co-occurrence network topology. We found significant correlations between stress, as described by a mean measure of upstream land use within a watershed, and topological measures of co-occurrence networks such as network size ($r = -.81$, $p < 10^{-4}$), connectance ($r = .31$, $p < 10^{-4}$), mean co-occurrence strength ($r = .25$, $p < 10^{-4}$), degree heterogeneity ($r = -.10$, $p < 10^{-4}$), and modularity ($r = .11$, $p < 10^{-4}$). Using these five topological measures, we constructed a linear model of biotic integrity, here a composite of taxonomic and functional diversity known as the California Stream Condition Index, of groups of BMI communities within a watershed. This model can account for 66% of among-watershed variation in the mean biotic integrity of communities. These observations imply a role for co-occurrence networks in assessing the current status of biotic integrity for BMI communities, as well as their potential use in assessing other ecological communities.

Citation

Simons, A.L., R.D. Mazor, S. Theroux. 2019. Using Co-occurrence Network Topology in Assessing Ecological Stress in Benthic Macroinvertebrate Communities. *Ecology and Evolution* DOI:10.1002/ece3.5751.

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Using alpha, beta, and zeta diversity in describing the health of stream-based benthic macroinvertebrate communities

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Abstract

Ecological monitoring of streams has frequently focused on measures describing the taxonomic, and sometimes functional, α diversity of benthic macroinvertebrates (BMIs) within a single sampled community. However, as many ecological processes effectively link BMI stream communities there is a need to describe groups of communities using measures of regional diversity. Here we demonstrate a role for incorporating both a traditional pairwise measure of community turnover, β diversity, in assessing community health as well as ζ diversity, α more generalized framework for describing similarity between multiple communities. Using 4,395 samples of BMI stream communities in California, we constructed a model using measures of α, β, and ζ diversity, which accounted for 71.7% of among-watershed variation in the mean health of communities, as described by the California Streams Condition Index (CSCI). We also investigated the use of ζ diversity in assessing models of stochastic vs. niche assembly across communities of BMIs within watersheds, with the niche assembly model found to be the likelier of the two.

Citation

Simons, A.L., R.D. Mazor, E.D. Stein, S. Nuzhdin. 2019. Using alpha, beta, and zeta diversity in describing the health of stream-based benthic macroinvertebrate communities. *Ecological Applications* DOI:10.1002/eap.1896.

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Benthic habitat condition of the continental shelf surrounding oil and gas platforms in the Santa Barbara Channel, Southern California

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Abstract

The continental shelf of southern California is an important location for the extraction of petroleum and natural gas. Many platforms in the region have been operating for more than four decades and are being targeted for decommissioning. Information on the condition of surrounding habitats to the platforms will be important for regulators. The condition of sediments near (250 m–2 km) four active oil/gas platforms was evaluated with measures of macrobenthic infauna, toxicity, and chemical composition using standardized assessment

indices and compared to that of equivalent locations across the region without platforms. Assessment scores indicated that the sediments surrounding the oil platforms were in a relatively good state, with reference-condition infauna, minimal levels of chemical exposure, and five instances (25% of samples) of low-level toxicity. Samples from around the oil platforms were in overall similar condition to the region, with slightly better condition infauna, nearly identical chemistry, and slightly worse toxicity.

CITATION

Gillett, D.J., L. Gisbane, K.C. Schiff. 2020. Benthic habitat condition of the continental shelf surrounding oil and gas platforms in the Santa Barbara Channel, Southern California. *Marine Pollution Bulletin* DOI:10.1016/j.marpolbul.2020.111662.

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Full text available online: www.sccwrp.org/publications

Good practices for species distribution modeling of deep-sea corals and sponges for resource management: Data collection, analysis, validation, and communication

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ABSTRACT

Resource managers in the United States and worldwide are tasked with identifying and mitigating trade-offs between human activities in the deep sea (e.g., fishing, energy development, and mining) and their impacts on habitat-forming invertebrates, including deep-sea corals, and sponges (DSCS). Related management decisions require information about where DSCS occur and in what densities. Species distribution modeling (SDM) provides a cost-effective means of identifying potential DSCS habitat over large areas to inform these management decisions and data collection. Here we describe good practices for DSCS SDM, especially in the context of data collection and management applications. Managers typically need information regarding DSCS encounter probabilities, densities, and sizes, defined at sub-regional to basin-wide scales and validated using subsequent, targeted data collections. To realistically achieve these goals, analysts should integrate available data sources in SDMs including fine-scale visual sampling and broad-scale resource surveys (e.g., fisheries trawl surveys), include environmental predictor variables representing multiple spatial scales, model residual spatial autocorrelation, and quantify prediction uncertainty. When possible, models fitted to presence-absence and density data are preferred over models fitted only to presence data, which are difficult to validate and can confound estimated probability of occurrence or density with sampling effort. Ensembles of models can provide robust predictions, while multi-species models leverage information across taxa, and facilitate community inference. To facilitate the use of models by managers, predictions should be expressed in units that are widely understood and validated at an appropriate spatial scale using a sampling design that provides strong statistical inference. We present three case studies for the Pacific Ocean that illustrate good practices with respect to data collection, modeling, and validation; these case studies demonstrate it is possible to implement our good practices in real-world settings.

CITATION

Winship, A.J., J.T. Thorson, M.E. Clarke, H.M. Coleman, B. Costa, S.E. Georgian, D.J. Gillett, A. Gruss, M.J. Henderson, T.F. Hourigan, D.D. Huff, N. Kreidler, J.L. Pirtle, J.V. Olson, M. Poti, C.N. Rooper, M.F. Sigler, S. Veihman, C.E. Whitmire. 2020. Good Practices for Species Distribution Modeling of Deep-Sea Corals and Sponges for Resource Management: Data Collection, Analysis, Validation, and Communication. *Frontiers in Marine Science* DOI:10.3389/fmars.2020.00303.

SCCWRP Journal Article #1138
Full text available online: www.sccwrp.org/publications

A decision framework for evaluating bioassessment samples and landscape models

Marcus Beck[1], Raphael Mazor[1]

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

CITATION

Beck, M.W., R.D. Mazor. 2020. A decision framework for evaluating bioassessment samples and landscape models. Technical Report 1115. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1115
Full text available online: www.sccwrp.org/publications

The Stream Quality Index: A multi-indicator tool for enhancing environmental management communication

Marcus W. Beck[1], Raphael D. Mazor[1], Susanna Theroux[1], Kenneth C. Schiff[1]

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

CITATION

Beck, M., R.D. Mazor, S. Theroux, K.C. Schiff. 2019. The Stream Quality Index: A Multi-Indicator Tool for Enhancing Environmental Management Communication. Technical Report 1080. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1080
Full text available online: www.sccwrp.org/publications

Assessing the representativeness of bioassessment samples using spatial statistical networks (SSNs) for watersheds in California: A guide for aquatic resource managers

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[2]*Central Coast Wetlands Group, Moss Landing, CA*

CITATION

Mazor, R.D., A. Santana, C. Endris, K. O'Connor. 2020. Assessing the representativeness of bioassessment samples using spatial statistical networks (SSNs) for watersheds in California: A guide for aquatic resource managers. Technical Report 1143. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1143
Full text available online: www.sccwrp.org/publications

Methods and guidance on assessing the ecological functioning of submerged aquatic vegetation in Southern California estuaries and embayments

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CITATION

McCune, K., D.J. Gillett, E.D. Stein. 2020. Methods and Guidance on Assessing the Ecological Functioning of Submerged Aquatic Vegetation in Southern California Estuaries and Embayments. Technical Report 1136. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1136
Full text available online: www.sccwrp.org/publications

Calibration of the multivariate AZTI Marine Biotic Index (M-AMBI) for potential inclusion into California sediment quality objective assessments in San Francisco Bay

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CITATION

Gillett, D.J., A.N. Parks, S.M. Bay. 2019. Calibration of the Multivariate AZTI Marine Biotic Index (M-AMBI) for Potential Inclusion into California Sediment Quality Objective Assessments in San Francisco Bay. Technical Report 1070. San Francisco Estuary Institute. Richmond, CA.

SCCWRP Technical Report #1070
Full text available online: www.sccwrp.org/publications

Benthic infauna of the Southern California Bight continental slope: Characterizing community structure for the development of an index of disturbance

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[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[2]*Bureau of Ocean Energy Management, Point Conception, CA*

CITATION

Gillett, D.J., L. Gisbane, K.C. Schiff. 2019. Benthic Infauna of the Southern California Bight Continental Slope: Characterizing Community Structure for the Development of an Index of Disturbance. Technical Report 1096. US Department of the Interior, Bureau of Ocean Energy Management. Camarillo, CA.

SCCWRP Technical Report #1096
Full text available online: www.sccwrp.org/publications

Cross-shelf habitat suitability modeling: Characterizing potential distributions of deep-sea corals, sponges, and macrofauna offshore of the US West Coast

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[9]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[10]*Bureau of Ocean Energy Management, Camarillo, CA*

CITATION

Poti, M., S.K. Henkel, J.J. Bizzarro, T.F. Hourigan, M.E. Clarke, C.E. Whitmire, A. Powell, M.M. Yoklavich, L. Bauer, A.J. Winship, M. Coyne, D.J. Gillett, L. Gilbane, J. Christensen, C.F.G. Jeffrey. 2020. Cross-Shelf Habitat Suitability Modeling: Characterizing Potential Distributions of Deep-Sea Corals, Sponges, and Macrofauna Offshore of the US West Coast. Technical Report 1171. U.S. Department of the Interior, Bureau of Ocean Energy Management. Camarillo, CA.

SCCWRP Technical Report #1171
Full text available online: www.sccwrp.org/publications

Cross-shelf habitat suitability modeling for benthic macrofauna

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[2]*Bureau of Ocean Energy Management, Camarillo, CA*
[3]*Southern California Coastal Water Research Project, Costa Mesa, CA*

CITATION

Henkel, S.K., L. Gilbane, A.J. Phillips, D.J. Gillett. 2020. Cross-Shelf Habitat Suitability Modeling for Benthic Macrofauna. Technical Report 1173. U.S. Department of the Interior, Bureau of Ocean Energy Management. Camarillo, CA.

SCCWRP Technical Report #1173
Full text available online: www.sccwrp.org/publications

Beta version of stream flow classification tool unveiled

SCCWRP and its partners have completed development of the beta version of a tool that can rapidly distinguish among perennial, intermittent and ephemeral streams across the U.S. Southwest, paving the way for the tool's initial rollout across an area stretching from California to Texas.

The Streamflow Duration Assessment Method classification tool, completed in beta form in 2020, uses easily observable field indicators – including presence of wetland vegetation and specific types of aquatic insects – to classify streams based on the duration of their surface flows. It is a collaboration of SCCWRP, the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers.

Ephemeral streams are water bodies that experience surface flows only after rain events, whereas intermittent streams experience sustained seasonal flows from snow melt and groundwater.

The tool is designed to support regulatory programs that require stream flow duration classifications, including a recent federal rule change that relies on stream flow duration to identify Waters of the United States.

SCCWRP and its partners will train state and federal agencies in the tool's use in 2021. The project team also has been calibrating the tool for use in other U.S. regions, including the Arid Southwest, Western Mountains and Great Plains.

Researchers have developed a tool that can rapidly distinguish among perennial, intermittent and ephemeral streams in the U.S. Southwest, including this tributary of Agua Caliente Creek in San Diego that is classified as an ephemeral stream.

Two case studies demonstrate how to use statewide framework for setting environmental flow targets

SCCWRP and its partners have initiated a pair of Southern California studies demonstrating how water resources managers can apply the California Environmental Flows Framework to set stream environmental flow targets that optimally protect the ecological and societal benefits provided by these flows.

The framework, expected to be finalized in 2021, is being applied to a study that will determine the effects of diverting treated wastewater effluent and runoff from the Los Angeles River for water recycling purposes. The framework also is being applied to a study examining how to implement flow-capture BMPs (best management practices) in San Juan Creek in Orange County to restore more natural flow patterns to the watershed.

The studies, launched in 2018 and 2019, respectively, will examine a range of potential flow management strategies for achieving desired management goals.

The framework is intended to help managers set optimal flow targets for streams statewide.

Treated wastewater effluent is discharged into the Los Angeles River from a nearby water reclamation plant. Water-quality managers for the effluent-dominated river have initiated a study to explore the potential ecological and recreational effects of diverting effluent and runoff from the river for water recycling purposes.

Study suggests not all strategies to protect health of erosion-prone streams created equal

SCCWRP and its partners have completed an analysis shedding light on whether next-generation management strategies for reducing erosion risk in streams could be more effective at protecting a stream's ecological health than traditional approaches that rely on channel hardening.

The study, completed in 2020, found that the biological integrity of hydromodification-prone streams is much more likely to be degraded in streams lined with concrete, rocks and other armoring modifications than in non-armored streams, where low-impact development (LID) and other strategies are often deployed instead. LID, which is a newer approach to guarding against flooding and erosion, is designed to minimize direct channel hardening that can be harmful to aquatic life.

The study underscores the potential of LID strategies to protect stream biology better than traditional channel hardening.

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Targeted hydrologic model calibration to improve prediction of ecologically-relevant flow metrics

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ABSTRACT

River flows exert dominant controls on in-stream biota. Quantifying linkages between hydrology and biology is important for assessing the effects of flow alteration on ecological functions. Hydrologic models are often used to quantify these flow-ecology relationships and guide management actions. Traditional model calibration techniques typically focus on a best overall fit criterion that may not be suitable for environmental flow applications where certain elements of the flow regime exert a dominant influence on biotic composition. We present an approach for hydrologic model calibration that improves the accuracy of calculated flow metrics known to be significant drivers of ecosystem response. First, we developed regional flow-ecology relationships based on streamflow gage and benthic macroinvertebrate data from southern California to determine which streamflow metrics best explain variability in taxonomic and trait-based biotic indices. Next, we developed and calibrated a series of hydrologic models to minimize error in these important flow metrics. For our study sites, flow flashiness and low flow frequency (indicative of drying) were found to best explain biotic condition. Hydrologic models calibrated specifically to minimize errors in these flow metrics predicted macroinvertebrate indices better than models calibrated to maximize fit to the overall flow regime. This ecological-calibration approach requires some a priori knowledge of flow-ecology relationships, but it produces results that can improve assessment of the impacts of changing flow regimes on biota and guide the development of strategies to mitigate ecological degradation.

CITATION

Parker, S.R., S.K. Adams, R.W. Lammers, E.D. Stein, B.P. Bledsoe. 2019. Targeted hydrologic model calibration to improve prediction of ecologically-relevant flow metrics. *Journal of Hydrology* 573:546-556.

SCCWRP Journal Article #1069
Full text available by request: pubrequest@sccwrp.org

Modelling runoff and sediment loads in a developing coastal watershed of the US-Mexico border

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ABSTRACT

Urbanization can increase sheet, rill, gully, and channel erosion. We quantified the sediment budget of the Los Laureles Canyon watershed (LLCW), which is a mixed rural-urbanizing catchment in Northwestern Mexico, using the AnnAGNPS model and field measurements of channel geometry. The model was calibrated with five years of observed runoff and sediment loads and used to evaluate sediment reduction under a mitigation scenario involving paving roads in hotspots of erosion. Calibrated runoff and sediment load had a mean-percent-bias of 28.4 and − 8.1, and root-mean-square errors of 85% and 41% of the mean, respectively. Suspended sediment concentration (SSC) collected at different locations during one storm-event correlated with modeled SSC at those locations, which suggests that the model represented spatial variation in sediment production. Simulated gully erosion represents 16%–37% of hillslope sediment production, and 50% of the hillslope sediment load is produced by only 23% of the watershed area. The model identifies priority locations for sediment control measures, and can be used to identify tradeoffs between sediment control and runoff production. Paving roads in priority areas would reduce total sediment yield by 30%, but may increase peak discharge moderately (1.6%–21%) at the outlet.

CITATION

Gudino-Elizondo, N., T.W. Biggs, R.L. Bingner, E.J. Langendoen, T. Kretzschmar, E.V. Taguas, K.T. Taniguchi-Quan, D. Liden, Y. Yuan. 2019. Modelling Runoff and Sediment Loads in a Developing Coastal Watershed of the US-Mexico Border. *Water* 11:1024.

SCCWRP Journal Article #1078
Full text available online: www.sccwrp.org/publications

A functional flows approach to selecting ecologically relevant flow metrics for environmental flow applications

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Abstract

The science and practice of environmental flows have advanced significantly over the last several decades. Most environmental flow approaches require quantifying the relationships between hydrologic change and biologic response, but this can be challenging to determine and implement due to high data requirements, limited transferability, and the abundance of hydrologic metrics available for evaluation. We suggest that a functional flows approach, focusing on elements of the natural flow regime known to sustain important ecosystem processes, offers a pathway for linking understanding of ecosystem processes with discrete, quantifiable measures of the flow regime for a broad range of native taxa and assemblages. Functional flow components can be identified as distinct aspects of the annual hydrograph that support key biophysical processes, such as wet season flood flows or spring recession flows, and then quantified by flow metrics, such as 5% exceedance flow or daily percent decrease in flow, respectively. By selecting a discrete set of flow metrics that measure key functional flow components, the spatial and temporal complexity of flow regimes can be managed in a holistic manner supportive of multiple ecological processes and native aquatic species requirements. We provide an overview of the functional flows approach to selecting a defined set of flow metrics and illustrate its application in two seasonally variable stream systems. We further discuss how a functional flows approach can be utilized as a conceptual model both within and outside of existing environmental flow frameworks to guide consideration of ecological processes when designing prescribed flow regimes.

Citation

Yarnell, S.M., E.D. Stein, J.A. Webb, T. Grantham, R.A. Lusardi, J. Zimmerman, R.A. Peek, B.A. Lane, J. Howard, S. Sandoval-Solis. 2020. A Functional Flows Approach to Selecting Ecologically Relevant Flow Metrics for Environmental Flow Applications. *River Research and Applications* DOI:10.1002/rra.3575.

SCCWRP Journal Article #1104
Full text available by request: pubrequest@sccwrp.org

Classifying streamflow duration: The scientific basis and an operational framework for method development

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Abstract

Streamflow duration is used to differentiate reaches into discrete classes (e.g., perennial, intermittent, and ephemeral) for water resource management. Because the depiction of the extent and flow duration of streams via existing maps, remote sensing, and gauging is constrained, field-based tools are needed for use by practitioners and to validate hydrography and modeling advances. Streamflow Duration Assessment Methods (SDAMs) are rapid, reach-scale indices or models that use physical and biological indicators to predict flow duration class. We review the scientific basis for indicators and present conceptual and operational frameworks for SDAM development. Indicators can be responses to or controls of flow duration. Aquatic and terrestrial responses can be integrated into SDAMs, reflecting concurrent increases and decreases along the flow duration gradient. The conceptual framework for data-driven SDAM development shows interrelationships among the key components: study reaches, hydrologic data, and indicators. We present a generalized operational framework for SDAM development that integrates the data-driven components through five process steps: preparation, data collection, data analysis, evaluation, and implementation. We highlight priorities for the advancement of SDAMs, including expansion of gauging of nonperennial reaches, use of citizen science data, adjusting for stressor gradients, and statistical and monitoring advances to improve indicator effectiveness.

Citation

Fritz, K.M., T. Nadeau, J. Kelso, W.S. Beck, R.D. Mazor, R.A. Harrington, B.J. Topping. 2020. Classifying Streamflow Duration: The Scientific Basis and an Operational Framework for Method Development. *Water* DOI:10.3390/w12092545.

SCCWRP Journal Article #1147
Full text available online: www.sccwrp.org/publications

Environmental predictors of stream flow in semi-arid watersheds for biological assessments

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Abstract

The aim of this study is to test a spatially explicit statistical model to identify indicators of natural stream flow using readily available stream, climate and landscape data. Understanding flow behavior of unmonitored streams at different temporal scales using environmental indicators is of great interest considering the logistic constraints of providing comprehensive flow instrumentation for all stream reaches in a region. Our results have applications to assess human impact in watersheds, to study environmental changes in fresh water resources, and in the management of local ecosystem. This study uses classification and regression tree analysis to

identify significant explanatory variables for a predictive model of stream flow in semi-arid watersheds of Southern California, USA. The study collected 77 variables with 30 years record, for a set of 48 sites, interpolated to create raster files at 30m spatial resolution. After applying Pearson correlation analyses to eliminate redundant variables, nine variables were found to have strong positive predictive value for estimating stream flow at ungauged sites. Nine prediction rasters portraying spatial variation of stream flow for the study region at three key index months during wet, dry, and average rainfall conditions. The predictive power of the variables was tested and cross validated over a subset of data not included when building the model. Model validation by site at monthly temporal resolution showed mixed results. While some sites where accurately predicted others did not. The comparison of observed vs predicted values by month suggest that this statistically based approach is able to predict the general patterns of stream flow at the regional scale, however it may be inaccurate in estimating actual flow values by month since the models tends to under-predict monthly discharge.

CITATION

Giraldo, M.A., S. Dark, P. Pendleton, E.D. Stein, R.D. Mazor, J. Andreas. 2019. Environmental predictors of stream flow in semi-arid watersheds for biological assessments. *Ecological Indicators* 104:429-438.

SCCWRP Journal Article #1098
Full text available by request: pubrequest@sccwrp.org

Review of flow duration methods and indicators of flow duration in the scientific literature: Arid Southwest

Kenneth McCune[1], Raphael Mazor[1]

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CITATION

McCune, K., R.D. Mazor. 2019. Review of Flow Duration Methods and Indicators of Flow Duration in the Scientific Literature: Arid Southwest. Technical Report 1063. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1063
Full text available online: www.sccwrp.org/publications

Review of recreational uses and associated flow needs along the main-stem of Los Angeles river

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CITATION

Stein, E.D., Y. Sanchez. 2019. Review of Recreational Uses and Associated Flow Needs Along the Main-stem of Los Angeles River. Technical Report 1088. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1088
Full text available online: www.sccwrp.org/publications

Making the most of water for the environment: A functional flows approach for California's rivers

Sarah M. Yarnell[1], Eric D. Stein[2], Rob A. Lusardi[1], Theodore Grantham[3], Jeffrey Mount[1]

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[2]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[3]*Department of Environmental Science, Policy and Management, University of California, Berkeley, Berkeley, CA*

CITATION

Grantham, T., J. Mount, E.D. Stein, S.M. Yarnell. 2020. Making the Most of Water for the Environment: A Functional Flows Approach for California's Rivers. Technical Report 1142. Public Policy Institute of California. San Francisco, CA.

SCCWRP Technical Report #1142
Full text available online: www.sccwrp.org/publications

Validation of two streamflow-duration assessment methods (SDAMs) in the Arid Southwest of the United States

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[3]*Army Corps of Engineers, Washington, DC*

CITATION

Mazor, R.D., B. Topping, R. Kwok, T. Nadeau, R. Leidy, K. Fritz, R. Harrington, J. Kelso, A. Allen, J. Robb, G. David, S. Jensen. 2019. Validation of Two Streamflow-duration Assessment Methods (SDAMs) in the Arid Southwest of the United States. Technical Report 1100. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1100
Full text available online: www.sccwrp.org/publications

Analysis of the juvenile steelhead and stream habitat database, Santa Cruz County, California

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[2]*County of Santa Cruz, Santa Cruz, CA*
[3]*Moss Landing Marine Labs, Moss Landing, CA*

CITATION

Beck, M., K. Kittleson, K. O'Connor. 2019. Analysis of the Juvenile Steelhead and Stream Habitat Database, Santa Cruz County, California: Web Products and Recommendations. Technical Report 1082. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1082
Full text available online: www.sccwrp.org/publications

Modeling shows how nutrients can alter seawater pH, oxygen

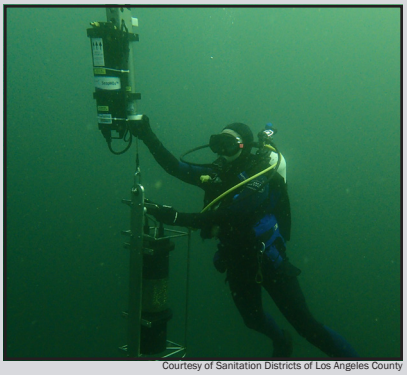
A research team that has been studying ocean acidification and hypoxia (OAH) conditions along the West Coast has developed and validated a computer model that predicts the influence of land-based discharges on OAH conditions in Southern California's coastal ocean.

The computer model, described in peer-reviewed journal articles published in 2020, used historical data from the late 1990s to simulate how land-based nutrient discharges trigger complex biogeochemical cycling processes that raise pH and dissolved oxygen levels in surface waters, while lowering pH and oxygen at depth.

The research team, which includes SCCWRP, found that the OAH model performed well, paving the way for researchers to use the model to simulate OAH conditions using modern-day nutrient discharge data. Researchers' goal is to determine which marine habitats are most vulnerable to OAH and to what extent, if any, local, land-based sources of nutrients are exacerbating effects on marine organisms.

Researchers spent years developing a downscaled, high-resolution OAH model for Southern California's coastal ocean and assessing its performance using locally collected field and remote-sensing data. The intensive performance assessment is essential for providing confidence that the model's predictions can be used reliably for management decision-making.

Researchers also are using the model to probe how scenarios involving wastewater recycling and nutrient management affect coastal OAH conditions.



Courtesy of Sanitation Districts of Los Angeles County

A pH sensor on a mooring line collects a continuous stream of seawater chemistry data. A team of researchers used locally collected field and remote-sensing data to assess the performance of a computer model that predicts how seawater chemistry will be altered by coastal ocean acidification and hypoxia.

Tools validated to set 'climate-ready' eutrophication targets for watershed

SCCWRP and its partners have validated an integrated toolkit of mechanistic computer models and statistical models to help managers set scientifically defensible eutrophication targets to protect the biological integrity of the Santa Margarita River watershed in the face of climate change.

The work, which is expected to wrap up in 2021, will enable researchers to assess how climate change and alterations to flow patterns and water temperature will impact eutrophication and biointegrity in the Santa Margarita River. The goal is to develop a watershed-based approach for customizing eutrophication targets that ensures that eutrophication management strategies are "climate-ready."

The work is serving as a key California case study for test-driving technical elements of a proposed State Water Board biointegrity-biostimulatory policy to govern the health of wadeable streams statewide.

Strategy developed to monitor freshwater HABs statewide

SCCWRP and the State Water Board have developed a proposed statewide strategy for boosting California's capacity to monitor the growing threat posed by harmful algal blooms (HABs) in California freshwater environments.

The freshwater HABs monitoring strategy, which was completed in draft form in 2020, offers a long-term vision for how California environmental managers should prioritize strategic, cost-effective investments in HABs monitoring to better protect human and ecosystem health. The document is expected to be finalized in 2021.

Many of the monitoring strategy recommendations, including developing a statewide HABs monitoring partner network, are intended to complement and build off existing freshwater HABs monitoring efforts and incident response reporting across California.

The strategy document, which is based on a vision developed by SCCWRP and the State Water Board for what a comprehensive monitoring framework should look like, represents the next phase in California's ongoing effort to more effectively manage freshwater HABs statewide.

A field crew uses an underwater autonomous vehicle, left, and a multispectral imaging sensor attached to a drone, right, to monitor cyanobacterial blooms in Lake Elsinore in Riverside County – in addition to collecting samples on a boat. Researchers have developed a proposed statewide strategy for monitoring freshwater blooms.

Submesoscale currents modulate the seasonal cycle of nutrients and productivity in the California current system

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[3]*Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, University of Toulouse, IRD, CNRS, CNES, UPS, Toulouse, France*
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ABSTRACT

In the California Current, subduction by mesoscale eddies removes nutrients from the coastal surface layer, counteracting upwelling and quenching productivity. Submesoscale eddies are also ubiquitous in the California Current, but their biogeochemical role has not been quantified yet in the region. Here, we present results from a physical-biogeochemical model of the California Current run at a resolution of 1 km, sufficient to represent submesoscale dynamics. By comparing it with a coarser simulation run at 4 km resolution, we demonstrate the importance of submesoscale currents for the seasonal cycles of nutrients and organic matter and highlight the existence of different regimes along a cross-shore gradient. In the productive coastal region, submesoscale currents intensify quenching and reduce productivity, further counteracting wind-driven upwelling. In the offshore oligotrophic region, submesoscale currents enhance the upward transport of nutrients, fueling a dramatic increase in new production. These effects are modulated by seasonality, strengthening near the coast during upwelling and offshore in wintertime. The intensification of the transport by submesoscale eddies drives an adjustment of the planktonic ecosystem, with a reduction of plankton biomass, productivity, and size near the coast and an increase offshore. In contrast, organic matter export by sinking particles and subduction of detritus and living cells are enhanced nearly everywhere. Similar processes are likely important in other regions characterized by seasonal upwelling, for example, other eastern boundary upwelling systems.

CITATION

Kessouri, F., D. Bianchi, L. Renault, J.C. McWilliams, H. Frenzel, C.A. Deutsch. 2020. Submesoscale Currents Modulate the Seasonal Cycle of Nutrients and Productivity in the California Current System. *Global Biogeochemical Cycles* DOI:10.1029/2020GB006578.

SCCWRP Journal Article #1158
Full text available by request: pubrequest@sccwrp.org

Co-occurring dissolved algal toxins observed at multiple coastal sites in Southern California via solid phase adsorption toxin tracking

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[3]*Orange County Sanitation District, Fountain Valley, CA*

ABSTRACT

Algal toxins (domoic acid, saxitoxin, okadaic acid) were monitored at seven locations off southern California using Solid Phase Adsorption Toxin Tracking. At least two types of toxins were found at all locations, with cooccurrence of two and three toxins in 12% and 10% of samples, respectively. This study expands our limited understanding of the simultaneous presence of multiple algal toxins along the coast and raises questions regarding the potential health ramifications of such co-occurrences.

CITATION

Smith, J., A. Lie, E.L. Seubert, N. Crowley, G. Robertson, D.A. Caron. 2019. Co-occurring Dissolved Algal Toxins Observed at Multiple Coastal Sites in Southern California via Solid Phase Adsorption Toxin Tracking. *Toxicon* DOI:10.1016/j.toxicon.2019.10.005.

SCCWRP Journal Article #1097
Full text available by request: pubrequest@sccwrp.org

Colored Dissolved Organic Matter (CDOM) as a tracer of effluent plumes in the coastal ocean

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[2]*California State Water Board, Division of Water Quality, Sacramento, CA*
[3]*City of San Diego Public Utilities Department, San Diego, CA*
[4]*Los Angeles County Sanitation District (LACSD), Whittier, CA*
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ABSTRACT

Mapping wastewater effluent plumes is typically conducted using ammonia as a tracer, but this provides low spatial resolution since it is collected as discrete bottle samples. Here we evaluate the use of colored dissolved organic matter fluorescence (CDOM) collected continuously with a CTD+ water column profiler as potential plume tracer alternative. We developed an algorithm for plume detection based on the image segmentation approach in 3D space and validated it against interpolated ammonia values collected during fourteen years of water quality monitoring (2004–2017) around three southern California ocean outfalls. There was 78%–81% agreement between plume site identification by CDOM and ammonia methods at the three outfalls, with an almost equal

fraction of the differences attributable to apparent error from each tracer. The biggest shortcoming of using ammonia concentration was its rapid transformation in seawater via nitrification or biological uptake, which is most problematic at stations at the plume perimeter. Shortcomings of the CDOM method include calibration problems, inappropriate excitation/emission characteristics of standard WETStar fluorometers and non-effluent (confounding) sources of CDOM in seawater around the outfalls, but these are largely correctable and are outweighed by the greater spatial and temporal resolution this method offers.

Citation

Nezlin, N.P., C. Beegan, A. Feit, J.R. Gully, A. Latker, K. McLaughlin, M.J. Mengel, G.L. Robertson, A. Steele, S.B. Weisberg. 2020. Colored Dissolved Organic Matter (CDOM) as a tracer of effluent plumes in the coastal ocean. *Regional Studies in Marine Science* DOI:10.1016/j.rsma.2020.101163.

SCCWRP Journal Article #1111
Full text available by request: pubrequest@sccwrp.org

Assessment of the cumulative effects of restoration activities on water quality in Tampa Bay, Florida

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Abstract

Habitat and water quality restoration projects are commonly used to enhance coastal resources or mitigate the negative impacts of water quality stressors. Significant resources have been expended for restoration projects, yet much less attention has focused on evaluating broad regional outcomes beyond site-specific assessments. This study presents an empirical framework to evaluate multiple datasets in the Tampa Bay area (Florida, USA) to identify (1) the types of restoration projects that have produced the greatest improvements in water quality and (2) time frames over which different projects may produce water quality benefits. Information on the location and date of completion of 887 restoration projects from 1971 to 2017 were spatially and temporally matched with water quality records at each of the 45 long-term monitoring stations in Tampa Bay. The underlying assumption was that the developed framework could identify differences in water quality changes between types of restoration projects based on aggregate estimates of chlorophyll-a concentrations before and after the completion of one to many projects. Water infrastructure projects to control point source nutrient loading into the Bay were associated with the highest likelihood of chlorophylla reduction, particularly for projects occurring prior to 1995. Habitat restoration projects were also associated with reductions in chlorophyll-a, although the likelihood of reductions from the cumulative effects of these projects were less than those from infrastructure improvements alone. The framework is sufficiently flexible for application to different spatiotemporal contexts and could be used to develop reasonable expectations for implementation of future water quality restoration activities throughout the Gulf of Mexico.

Citation

Beck, M., E.T. Sherwood, J.R. Henkel, K. Dorans, K. Ireland, P. Varela. 2019. Assessment of the Cumulative Effects of Restoration Activities on Water Quality in Tampa Bay, Florida. *Estuaries and Coasts* DOI:10.1007/s12237-019-00619-w.

SCCWRP Journal Article #1086
Full text available online: www.sccwrp.org/publications

Emission sources, fluxes and spatiotemporal distribution of nutritive resources

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Abstract

One of the most critical issues in oceanographic and climatic sciences is phytoplankton dynamics: on this depend both the sequestration of excess atmospheric CO_2 through photosynthesis and the proper functioning of marine food systems through plankton productivity. Biological productivity itself depends, to a very large extent, on the availability of nutrients. Hence, there is the need to fully understand the spatiotemporal variability of nutrient concentrations in the surface ocean, together with the physical, chemical and biological parameters that constrain this variability. The Mediterranean Sea (Med) is considered one of the least productive seas in the world [BET 98]. Nutrient concentrations exhibit a decreasing gradient from west to east [MOU 12] that is commonly viewed as a consequence of the peculiar, so-called "anti-estuarine" Med circulation described in the Chapter 3: low amounts of nutrients enter the Med in surface via the Gibraltar Strait, much of which is consumed along the way to the eastern basin, and then exported to deep layers. On the way back to Gibraltar, the remaining nutrients are mostly exported to the Atlantic Ocean, which results in a significant loss of nutritive resources.

Citation

Mignon, C., O. Pasqueron de Fommervault, F. Kessouri. 2020. Emission Sources, Fluxes and Spatiotemporal Distribution of Nutritive Resources. in: C. Mignon, P. Nival, A. Sciandra (eds.), *The Mediterranean Sea in the Era of Global Change 1: 30 Years of Multidisciplinary Study of the Ligurian Sea* pp. 105-138. Wiley. New York, NY.

SCCWRP Book Chapter #1114
Full text available by request: pubrequest@sccwrp.org

Phytoplankton decline in the eastern North Pacific transition zone associated with atmospheric blocking

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ABSTRACT

Global climate change can significantly influence oceanic phytoplankton dynamics, and thus biogeochemical cycles and marine food webs. However, associative explanations based on the correlation between chlorophyll-a concentration (Chl-a) and climatic indices is inadequate to describe the mechanism of the connection between climate change, large-scale atmospheric dynamics, and phytoplankton variability. Here, by analyzing multiple satellite observations of Chl-a and atmospheric conditions from National Center for Environmental Prediction/National Center for Atmospheric Research reanalysis datasets, we show that high-latitude atmospheric blocking events over Alaska are the primary drivers of the recent decline of Chl-a in the eastern North Pacific transition zone. These blocking events were associated with the persistence of large-scale atmosphere pressure fields that decreased westerly winds and southward Ekman transport over the subarctic ocean gyre. Reduced southward Ekman transport leads to reductions in nutrient availability to phytoplankton in the transition zone. The findings describe a previously unidentified climatic factor that contributed to the recent decline of phytoplankton in this region and propose a mechanism of the top-down teleconnection between the high-latitude atmospheric circulation anomalies and the subtropical oceanic primary productivity. The results also highlight the importance of understanding teleconnection among atmosphere– ocean interactions as a means to anticipate future climate change impacts on oceanic primary production.

CITATION

Le, C., S. Wu, C. Hu, M. Beck, X. Yang. 2019. Phytoplankton decline in the eastern North Pacific transition zone associated with atmospheric blocking. *Geophysical Research Letters* DOI:10.1111/gcb.14737.

SCCWRP Journal Article #1085
Full text available by request: pubrequest@sccwrp.org

Comparison of novel passive sampling methods to identify cyanotoxins and their sources

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CITATION

Du, B., J. Smith, K. Maruya, C.S. Wong. 2020. Comparison of Novel Passive Sampling Methods to Identify Cyanotoxins and their Sources. Technical Report 1123. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1123
Full text available online: www.sccwrp.org/publications

Biological tools developed to support acidification modeling

SCCWRP and its partners have developed a suite of biological tools to assess the effects of ocean acidification and hypoxia (OAH) on coastal marine life, part of a multi-year initiative that involves developing a West Coast computer model to predict how intensifying OAH conditions in the coming years will alter ecologically and economically important habitats.

The tools, which have been incrementally developed over the past few years, are designed to assess potential biological effects from ocean acidification (OA) and low dissolved-oxygen levels, respectively:

» **OA biological thresholds**: Global scientific experts in the biological effects of ocean acidification have reached consensus on the biological thresholds at which vulnerable marine species can be expected to be adversely impacted by OA conditions. The resesarchers have developed OA thresholds for three species already; a fourth is under development.

» **Metabolic indices**: A research team that includes SCCWRP has developed a series of West Coast indices that estimate the extent to which the habitats of keystone marine species will be squeezed by reduced oxygen availability and changing temperature. Each of the species-specific "metabolic" indices quantifies the temperature-dependent availability of dissolved oxygen in a species' marine habitat in relation to the level of oxygen it requires for survival. Metabolic indices were unveiled in 2020 for nine West Coast species; six other indices are under development.

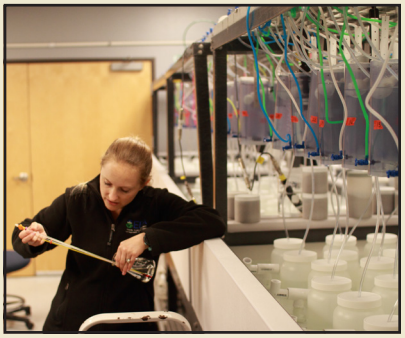
A pteropod, or sea snail, with pit marks on its shell, shows signs of shell dissolution in response to changing seawater chemistry. Researchers are developing tools to assess these adverse effects on coastal marine life.

Dynamic exposure lab replicates fluctuating environmental conditions

SCCWRP has constructed a state-of-the-art dynamic exposure laboratory to study how aquatic organisms respond to fluctuations in pH, dissolved oxygen and other environmental parameters in a controlled setting – a type of experimental setup found in only a handful of labs worldwide.

The Dynamic Stressor Exposure Research Facility (DSERF), which was built in 2019, helps researchers better understand how these multi-stressor biological impacts are playing out in the real world. By automatically adjusting multiple parameters over the course of an experiment, researchers can more accurately mimic fluctuating environmental conditions, including tidal cycles, seasonal changes and projected future conditions linked to climate change.

Already, researchers have used the DSERF lab to examine the role that underwater kelp forests could play in mitigating ocean acidification for adjacent oyster farms, as well as the impact of low pH and low dissolved oxygen levels on the larvae of commercially important Dungeness crab. The co-occurring conditions could be interacting to exacerbate impacts.



SCCWRP's Dr. Ashley Parks uses a dynamic exposure laboratory to study how organisms respond to fluctuations in pH, dissolved oxygen and other environmental parameters, including those linked to climate change.

Climate change's impacts on sensitive aquatic life modeled for L.A. region

SCCWRP and its partners have completed a study examining how changing rainfall patterns and temperatures in the Los Angeles region stemming from climate change will impact sensitive aquatic environments.

The study, completed in 2019, found that some species such as the endangered arroyo toad – which is dependent on specific seasonal rainfall patterns – are expected to be significantly impacted. Other species sensitive to changes in water temperature could be similarly impacted.

The study involved using regional flow ecology relationships to model how projected changes in rainfall and temperature patterns over the next century can be expected to impact sensitive biological communities, then using this information for developing watershed vulnerability maps.

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Global observational needs and resources for marine biodiversity

Gabrielle Canonico[1], Pier Luigi Buttigieg[2], Enrique Montes[3], Frank E. Muller-Karger[3], Carol Stepien[4], Dawn Wright[5,6], Abigail Benson[7], Brian Helmuth[8], Mark Costello[9], Isabel Sousa-Pinto[10], Hanieh Saeedi[11,12], Jan Newton[13], Ward Appeltans[14], Nina Bednaršek[15], Levente Bodrossy[16], Benjamin D. Best[17], Angelika Brandt[11,12], Kelly D. Goodwin[18], Katrin Iken[19], Antonio C. Marques[20], Patricia Miloslavich[21,22], Martin Ostrowski[23], Woody Turner[24], Eric P. Achterberg[25], Tom Barry[26], Omar Defeo[27], Gregorio Bigatti[28.29], Lea-Anne Henry[30], Berta Ramiro-Sánchez[30], Pablo Durán[31], Telmo Morato[32], J. Murray Roberts[30], Ana García-Alegre[31], Mar Sacau Cuadrado[31], Bramley Murton[33]

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Abstract

The diversity of life in the sea is critical to the health of ocean ecosystems that support living resources and therefore essential to the economic, nutritional, recreational, and health needs of billions of people. Yet there is evidence that the biodiversity of many marine habitats is being altered in response to a changing climate and human activity. Understanding this change, and forecasting where changes are likely to occur, requires monitoring of organism diversity, distribution, abundance, and health. It requires a minimum of measurements including productivity and ecosystem function, species composition, allelic diversity, and genetic expression. These observations need to be complemented with metrics of environmental change and socio-economic drivers. However, existing global ocean observing infrastructure and programs often do not explicitly consider observations of marine biodiversity and associated processes. Much effort has focused on physical, chemical and some biogeochemical measurements. Broad partnerships, shared approaches, and best practices are now being organized to implement an integrated observing system that serves information to resource managers and decision-makers, scientists and educators, from local to global scales. This integrated observing system of ocean life is now possible due to recent developments among satellite, airborne, and *in situ* sensors in conjunction with increases in information system capability and capacity, along with an improved understanding of marine processes represented in new physical, biogeochemical, and biological models.

Citation

Canonico, G., P.L. Buttigieg, E. Montes, F.E. Muller-Karger, C. Steplen, D. Wright, A. Benson, B. Helmuth, M. Costello, I. Sousa-Pinto, H. Saeedi, J. Newton, W. Appeltabs, N. Bednarsek, L. Bodrossy, B.D. Best, A. Brandt, K.D. Goodwin, K. Iken, A.C. Marques, P. Miloslavich, M. Ostrowski, W. Turner, E.P. Achterberg, T. Barry, O. Defeo, G. Bigatti, L. Henry, B. Ramiro-Sanchez, P. Duran, T. Morato, J.M. Roberts, A. Garchia-Alegre, M.S. Cuadrado, B. Murton. 2019. Global Observational Needs and Resources for Marine Biodiversity. *Frontiers in Marine Science* 6:1-20.

SCCWRP Journal Article #1093
Full text available online: www.sccwrp.org/publications

Towards integrating evolution, metabolism, and climate change studies of marine ecosystems

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ABSTRACT

Global environmental changes are challenging the structure and functioning of ecosystems. However, a mechanistic understanding of how global environmental changes will affect ecosystems is still lacking. The complex and interacting biological and physical processes spanning vast temporal and spatial scales that constitute an ecosystem make this a formidable problem. A unifying framework based on ecological theory, that considers fundamental and realized niches, combined with metabolic, evolutionary, and climate change studies, is needed to provide the mechanistic understanding required to evaluate and forecast the future of marine communities, ecosystems, and their services.

CITATION

Baltar, F., B. Bayer, N. Bednarsek, S. Deppeler, R. Escribano, C.E. Gonzalez, R.L. Hansman, R.H. Mishra, M.A. Moran, D.J. Repeta, C. Robinson, E. Sintes, C. Tamburini, L.E. Valentin, G.J. Hemdi. 2019. Towards Integrating Evolution, Metabolism, and Climate Change Studies of Marine Ecosystems. *Trends in Ecology and Evolution* DOI:10.1016/j.tree.2019.07.003.

SCCWRP Journal Article #1092
Full text available online: www.sccwrp.org/publications

Systematic review and meta-analysis toward synthesis of thresholds of ocean acidification impacts on calcifying pteropods and interactions with warming

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ABSTRACT

Interpreting the vulnerability of pelagic calcifiers to ocean acidification (OA) is enhanced by an understanding of their critical thresholds and how these thresholds are modified by other climate change stressors (e.g., warming). To address this need, we undertook a three-part data synthesis for pteropods, one of the calcifying zooplankton group. We conducted the first meta-analysis and threshold analysis of literature characterizing pteropod responses to OA and warming by synthetizing dataset comprising of 2,097 datapoints. Meta-analysis revealed the extent to which responses among studies conducted on differing life stages and disparate geographies could be integrated into a common analysis. The results demonstrated reduced calcification, growth, development, and survival to OA with increased magnitude of sensitivity in the early life stages, under prolonged duration, and with the concurrent exposure of OA and warming, but not species-specific sensitivity. Second, breakpoint analyses identified OA thresholds for several endpoints: dissolution (mild and severe), calcification, egg development, shell growth, and survival. Finally, consensus by a panel of pteropod experts was used to verify thresholds and assign confidence scores for five endpoints with a sufficient signal: noise ratio to develop life-stage specific, duration-dependent thresholds. The range of aragonite saturation state from 1.5–0.9 provides a risk range from early warning to lethal impacts, thus providing a rigorous basis for vulnerability assessments to guide climate change management responses, including an evaluation of the efficacy of local pollution management. In addition, meta-analyses with OA, and warming shows increased vulnerability in two pteropod processes, i.e., shell dissolution and survival, and thus pointing toward increased threshold sensitivity under combined stressor effect.

CITATION

Bednarsek, N., R.A. Feely, E.L. Howes, B.P.V. Hunt, F. Kessouri, P. Leon, R. Lischka, A.E. Maas, K. McLaughlin, N.P. Nezlin, M. Sutula, S.B. Weisberg. 2019. Systematic Review and Meta-Analysis Toward Synthesis of Thresholds of Ocean Acidification Impacts on Calcifying Pteropods and Interactions With Warming. *Frontiers in Marine Science* 6:227.

SCCWRP Journal Article #1076
Full text available online: www.sccwrp.org/publications

Establishing targets for regional coastal wetland restoration planning using historical ecology and future scenario analysis: The past, present, future approach

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ABSTRACT

Regional approaches to coastal wetland restoration are one of the best ways to ensure that these threatened habitats persist in the face of sea level rise. Regional approaches provide a mechanism for prioritizing restoration actions in areas where future conditions will promote maximum resiliency while still providing for an appropriate composition of plant and animal habitats across the region as a whole. Developing a regional restoration strategy requires understanding historical losses relative to contemporary habitat distributions, predicting future changes due to sea level rise (and other stressors), and evaluating management actions with the potential to offset expected future losses. In this study, we present an approach to assess historical losses and future management options

for more than 100 individual wetlands along the Southern California (USA) coast ranging in size from a few tenths of a hectare to over 250 ha. This analysis was conducted to support development of a regional wetland strategy that will guide restoration in Southern California for the next several decades. The approach consisted of reconstructing historical wetland distribution using US Coast and Geodetic Survey T-sheets, mapping current wetlands and classifying them into archetypes that represent different settings and processes, and predicting future distributions based on a hypsometric model of elevation changes under various sea level rise and management scenarios. Historical analysis revealed that two-thirds of the 331 wetlands present in ca. 1850 and 75% of vegetated estuarine habitat area has been lost, with most losses occurring in small to medium size wetlands. Up to 69% of the remaining marshes and flats could be lost with 1.7 m of sea level rise, with an associated increase in subtidal habitat. However, potential future losses could be largely offset, and total area could increase under scenarios of facilitated wetland migration and sediment augmentation. Although the future distribution of wetlands would likely be different from current conditions, sufficient habitat would be provided region-wide.

CITATION

Stein, E.D., C.L. Doughty, J. Lowe, M. Cooper, E. Sloane, D. Bram. 2020. Establishing Targets for Regional Coastal Wetland Restoration Planning Using Historical Ecology and Future Scenario Analysis: The Past, Present, Future Approach. *Estuaries and Coasts* DOI:10.1007/s12237-019-00681-4.

SCCWRP Journal Article #1105
Full text available by request: pubrequest@sccwrp.org

Evaluating regional resiliency of coastal wetlands to sea level rise through hypsometry-based modeling

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ABSTRACT

Sea level rise (SLR) threatens coastal wetlands worldwide, yet the fate of individual wetlands will vary based on local topography, wetland morphology, sediment dynamics, hydrologic processes, and plant-mediated feedbacks. Local variability in these factors makes it difficult to predict SLR effects across wetlands or to develop a holistic regional perspective on SLR response for a diversity of wetland types. To improve regional predictions of SLR impacts to coastal wetlands, we developed a model that addresses the scale-dependent factors controlling SLR response and accommodates different levels of data availability. The model quantifies SLR-driven habitat conversion within wetlands across a region by predicting changes in individual wetland hypsometry. This standardized approach can be applied to all wetlands in a region regardless of data availability, making it ideal for modeling SLR response across a range of scales. Our model was applied to 105 wetlands in southern California that spanned a broad range of typology and data availability. Our findings suggest that if wetlands are confined to their current extents, the region will lose 12% of marsh habitats (vegetated marsh and unvegetated flats) with 0.6 m of SLR (projected for 2050) and 48% with 1.7 m of SLR (projected for 2100). Habitat conversion was more drastic in wetlands with larger proportions of marsh habitats relative to subtidal habitats and occurred more rapidly in small lagoons relative to larger sites. Our assessment can inform management of coastal wetland vulnerability, improve understanding of the SLR drivers relevant to individual wetlands, and highlight significant data gaps that impede SLR response modeling across spatial scales. This approach augments regional SLR assessments by considering spatial variability in SLR response drivers, addressing data gaps, and accommodating wetland diversity, which will provide greater insights into regional SLR response that are relevant to coastal management and restoration efforts.

CITATION

Doughty, C.L., K.C. Cavanaugh, R.F. Ambrose, E.D. Stein. 2019. Evaluating regional resiliency of coastal wetlands to sea level rise through hypsometry-based modeling. *Global Change Biology* 25:78-92.

SCCWRP Journal Article #1056
Full text available online: www.sccwrp.org/publications

Effects of elevated sea levels and waves on Southern California estuaries during the 2015–2016 El Niño

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ABSTRACT

The 2015–2016 El Niño provided insight into how low-inflow estuaries might respond to future climate regimes, including high sea levels and more intense waves. High waves and water levels coupled with low rainfall along the Southern California coastline provided the opportunity to examine how extreme

ocean forcing impacts estuaries independently from fluvial events. From November 2015 to April 2016, water levels were measured in 13 Southern California estuaries, including both intermittently closed and perennially open estuaries with varying watershed size, urban development, and management practices. Elevated ocean water levels caused raised water levels and prolonged inundation in all of the estuaries studied. Water levels inside perennially open estuaries mirrored ocean water levels, while those inside intermittently closed estuaries (ICEs) exhibited enhanced higher-high water levels during large waves, and tides were truncated at low tides due to a wave-built sand sill at the mouth, resulting in elevated detided water levels. ICEs closed when sufficient wave-driven sand accretion formed a barrier berm across the mouth separating the estuary from the ocean, the height of which can be estimated using estuarine lower-low water levels. During the 2015–2016 El Niño, a greater number of Southern California ICEs closed than during a typical year and ICEs that close annually experienced longer than normal closures. Overall, sill accretion and wave exposure were important contributing factors to individual estuarine response to ocean conditions. Understanding how estuaries respond to increased sea levels and waves and the factors that influence closures will help managers develop appropriate adaptation strategies.

Citation

Harvey, M.E., S.N. Giddings, E.D. Stein, J.A. Crooks, C. Whitcraft, T. Gallien, J.L. Largier, L.L. Tiefenthaler, H. Meltzer, G. Pawlak, K. Thorne, K. Johnston, R. Ambrose, S.C. Schroeter, H.M. Page, H. Elwany. 2020. Effects of Elevated Sea Levels and Waves on Southern California Estuaries During the 2015–2016 El Niño. *Estuaries and Coasts* DOI:10.1007/s12237-019-00676-1.

SCCWRP Journal Article #1107
Full text available online: www.sccwrp.org/publications

Barriers and opportunities for beneficial reuse of sediment to support coastal resilience

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Abstract

As urbanization and climate change alter sediment fluxes, relative sea level, and coastal erosion around the world, management of sediment as a resource is increasingly important. Sediment is needed to enhance marsh accretion rates, raise the grade elevation of development, and build up beaches and dunes. Beneficial reuse of sediment refers to the repurposing of local sources of sediment for these applications, material typically available from dredging or sediment capture infrastructure, and represents a more sustainable approach compared to the status-quo involving transport to and from distant locations. However, in many locations, beneficial reuse remains a concept or is constrained to small-scale applications. In this paper, we draw on interviews with coastal sediment managers and regulators in Southern California to identify barriers to beneficial reuse and opportunities to overcome them. Interviewees reported numerous regulatory, technical, psychological, financial, and interorganizational barriers in their watersheds and regions. By highlighting these barriers, we aim to identify systemic changes that would make beneficial reuse a realistic and accessible option for Southern California and elsewhere. Most prominently, a more flexible regulatory framework that allows sediment management practices to adapt over time, pilot studies to understand how beneficial reuse works in various settings, and educational programs for regulators and the public could make beneficial reuse a more widespread approach.

Citation

Ulibarri, N., K.A. Goodrich, P. Wagle, M. Brand, R. Matthew, E.D. Stein, B.F. Sanders. 2020. Barriers and opportunities for beneficial reuse of sediment to support coastal resilience. *Ocean and Coastal Management* DOI:10.1016/j.ocecoaman.2020.105287.

SCCWRP Journal Article #1134
Full text available by request: pubrequest@sccwrp.org

The impact of climate change induced alterations of streamflow and stream temperature on the distribution of riparian species

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Abstract

Distributions of riparian species will likely shift due to climate change induced alterations in temperature and rainfall patterns, which alter stream habitat. Spatial forecasting of suitable habitat in projected climatic conditions will inform management interventions that support wildlife. Challenges in developing forecasts include the need to consider the large number of riparian species that might respond differently to changing conditions and the need to evaluate the many different characteristics of streamflow and stream temperature that drive species-specific habitat suitability. In particular, in dynamic environments like streams, the short-term temporal resolution of species occurrence and streamflow need to be considered to identify the types of conditions that support various species. To address these challenges, we cluster species based on habitat characteristics to select habitat representatives and we evaluate regional changes in habitat suitability using short-term, temporally explicit metrics that

describe the streamflow and stream temperature regime. We use stream-specific environmental predictors rather than climatic variables. Unlike other studies, the stream-specific environmental predictors are generated from the time that species were observed in a particular reach, in addition to long term trends, to evaluate habitat preferences. With species occurrence data from local monitoring surveys and streamflow and stream temperature modeled from downscaled Coupled Model Intercomparison Project - Phase 5 (CMIP5) climate projections, we predict change in habitat suitability at the end-of-century. The relative importance of hydrology and stream temperature varied by cluster. High altitudinal, cold water species' distributions contracted, while lower elevation, warm water species distributions expanded. Modeling with short-term temporally explicit environmental metrics did produce different end-of-century projections than using long-term averages for some of the representative species. These findings can help wildlife managers prioritize conservation efforts, manage streamflow, initiate monitoring of species in vulnerable clusters, and address stressors, such as passage barriers, in areas projected to be suitable in future climate conditions.

CITATION

Taylor, J., E.D. Stein, M.W. Beck, R.F. Ambrose. 2020. The impact of climate change induced alterations of streamflow and stream temperature on the distribution of riparian species. *PLOS One* DOI:10.1371/journal.pone.0242682.

SCCWRP Journal Article #1181
Full text available online: www.sccwrp.org/publications

Natural and anthropogenic drivers of acidification in large estuaries

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ABSTRACT

Oceanic uptake of anthropogenic carbon dioxide (CO_2) from the atmosphere has changed ocean biogeochemistry and threatened the health of organisms through a process known as ocean acidification (OA). Such large-scale changes affect ecosystem functions and can have effects on societal uses, fisheries resources, and economies. In many large estuaries, anthropogenic CO_2-induced acidification is enhanced by strong stratification, long water residence times, eutrophication, and a weak acid–base buffer capacity. In this article, we review how a variety of processes influence aquatic acid–base properties in estuarine waters, including river–ocean mixing, upwelling, air–water gas exchange, biological production and subsequent respiration, anaerobic respiration, calcium carbonate ($CaCO_3$) dissolution, and benthic inputs. We emphasize the spatial and temporal dynamics of partial pressure of CO_2 (pCO_2), pH, and calcium carbonate mineral saturation states. Examples from three large estuaries—Chesapeake Bay, the Salish Sea, and Prince William Sound—are used to illustrate how natural and anthropogenic processes and climate change may manifest differently across estuaries, as well as the biological implications of OA on coastal calcifiers.

CITATION

Cai, W.J., R.A. Feely, J.M. Testa, M. Li, W. Evans, S.R. Alin, Y.Y. Xu, G. Pelletier, A. Ahmed, D.J. Greeley, J.A. Newton, N. Bednarsek. 2020. Natural and Anthropogenic Drivers of Acidification in Large Estuaries. *Annual Review of Marine Science* DOI:10.1146/annurev-marine-010419-011004.

SCCWRP Journal Article #1151
Full text available by request: pubrequest@sccwrp.org

Climate-driven aerobic habitat loss in the California Current System

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ABSTRACT

Climate warming is expected to intensify hypoxia in the California Current System (CCS), threatening its diverse and productive marine ecosystem. We analyzed past regional variability and future changes in the Metabolic Index (Φ), a species-specific measure of the environment's capacity to meet temperature-dependent organismal oxygen demand. Across the traits of diverse animals, Φ exhibits strong seasonal to interdecadal variations throughout the CCS, implying that resident species already experience large fluctuations in available aerobic habitat. For a key CCS species, northern anchovy, the long-term biogeographic distribution and decadal fluctuations in abundance are both highly coherent with aerobic habitat volume. Ocean warming and oxygen loss by 2100 are projected to decrease Φ below critical levels in 30 to 50% of anchovies' present range, including complete loss of aerobic habitat—and thus likely extirpation—from the southern CCS. Aerobic habitat loss will vary widely across the traits of CCS taxa, disrupting ecological interactions throughout the region.

CITATION

Howard, E.M., J.L. Penn, H. Frenzel, B.A. Seibel, D. Blanchi, L. Renault, F. Kessouri, M. Sutula, J.C. McWilliams, C. Deutsch. 2020. Climate-driven aerobic habitat loss in the California Current System. *Science Advances* DOI:10.1126/sciadv.aay3188.

SCCWRP Journal Article #1139
Full text available online: www.sccwrp.org/publications

Attributing causes of future climate change in the California Current System with multimodel downscaling

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ABSTRACT

Coastal winds in the California Current System (CCS) are credited with the high productivity of its planktonic ecosystem and the shallow hypoxic and corrosive waters that structure diverse macrofaunal habitats. These winds thus are considered a leading mediator of climate change impacts in the CCS and other Eastern Boundary Upwelling systems. We use an eddy-permitting regional model to downscale the response of the CCS to three of the major distinct climate changes commonly projected by global Earth System Models: regional winds, ocean warming and stratification, and remote water chemical properties. An increase in alongshore winds intensifies spring upwelling across the CCS, but this response is muted by increased stratification, especially during summer. Despite the seasonal shift in regional wind-driven upwelling, basin-scale changes are the decisive factor in the response of marine ecosystem properties including temperature, nutrients, productivity, and oxygen. Downscaled temperature increases and dissolved oxygen decreases are broadly consistent with coarse resolution Earth System Models, and these projected changes are large and well constrained across the models, whereas nutrient and productivity changes are small compared to the intermodel spread. These results imply that global models with poor resolution of coastal processes nevertheless yield important information about the dominant climate impacts on coastal ecosystems.

CITATION

Howard, E.M., H. Frenzel, F. Kessouri, L. Renault, D. Bianchi, J.C. McWilliams, C.A. Deutsch. 2020. Attributing Causes of Future Climate Change in the California Current System With Multimodel Downscaling. *Global Biogeochemical Cycles* DOI:10.1029/2020GB006646.

SCCWRP Journal Article #1159
Full text available online: www.sccwrp.org/publications

Chemical exposure due to anthropogenic ocean acidification increases risks for estuarine calcifiers in the Salish Sea: Biogeochemical model scenarios

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ABSTRACT

Ocean acidification (OA) is projected to have profound impacts on marine ecosystems and resources, especially in estuarine habitats. Here, we describe biological risks under current levels of exposure to anthropogenic OA in the Salish Sea, an estuarine system that already experiences inherently low pH and aragonite saturation state (Ar) conditions. We used the Pacific Northwest National Laboratory and Washington State Department of Ecology Salish Sea biogeochemical model (SSM) informed by a selection of OA-related biological thresholds of ecologically and economically important calcifiers, pteropods, and Dungeness crabs. The SSM was implemented to assess current exposure and associated risk due to reduced Ar and pH conditions with respect to the magnitude, duration, and severity of exposure below the biological thresholds in the Salish Sea in comparison to the pre-industrial era. We further investigated the individual effects of atmospheric CO_2 uptake and nutrient-driven eutrophication on changes in chemical exposure since pre-industrial times. Our model predicts average decreases in Ar and pH since pre-industrial times of about 0.11 and 0.06, respectively, in the top 100 m of the water column of the Salish Sea. These decreases predispose pelagic calcifiers to increased duration, intensity, and severity of exposure. For pteropods, present-day exposure is below the thresholds related to sublethal effects across the entire Salish Sea basin, while mortality threshold exposure occurs on a spatially limited basis. The greatest risk for larval Dungeness crabs is associated with spatially limited exposures to low calcite saturation state in the South Sound in the springtime, triggering an increase in internal dissolution. The main anthropogenic driver behind the predicted impacts is atmospheric CO_2 uptake, while nutrient-driven eutrophication plays only a marginal role over spatially and temporally limited scales. Reduction of CO_2 emissions can help sustain biological species vital for ecosystem functions and society mechanoreceptors with important sensory and behavioral functions, a pathway of sensitivity to OA. Carapace dissolution is negatively related to crab larval width, demonstrating a basis for energetic trade-offs. Using a retrospective prediction from a regression models, we estimate an 8.3% increase in external carapace dissolution over the last two decades and identified a set of affected OA-related sublethal pathways to inform future risk assessment studies of Dungeness crabs.

CITATION
Bednarsek, N., G. Pelletier, A. Ahmed, R.A. Feely. 2020. Chemical Exposure Due to Anthropogenic Ocean Acidification Increases Risks for Estuarine Calcifiers in the Salish Sea: Biogeochemical Model Scenarios. *Frontiers in Marine Science* DOI:10.3389/fmars.2020.00580.

SCCWRP Journal Article #1129
Full text available online: www.sccwrp.org/publications

Severe biological effects under present-day estuarine acidification in the seasonally variable Salish Sea

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ABSTRACT
Estuaries are recognized as one of the habitats most vulnerable to coastal ocean acidification due to seasonal extremes and prolonged duration of acidified conditions. This is combined with co-occurring environmental stressors such as increased temperature and low dissolved oxygen. Despite this, evidence of biological impacts of ocean acidification in estuarine habitats is largely lacking. By combining physical, biogeochemical, and biological time-series observations over relevant seasonal-to-interannual time scales, this study is the first to describe both the spatial and temporal variation of biological response in the pteropod *Limacina helicina* to estuarine acidification in association with other stressors. Using clustering and principal component analyses, sampling sites were grouped according to their distribution of physical and biogeochemical variables over space and time. This identified the most exposed habitats and time intervals corresponding to the most severe negative biological impacts across three seasons and three years. We developed a cumulative stress index as a means of integrating spatial-temporal OA variation over the organismal life history. Our findings show that over the 2014– 2016 study period, the severity of low aragonite saturation state combined with the duration of exposure contributed to overall cumulative stress and resulted in severe shell dissolution. Seasonally-variable estuaries such as the Salish Sea (Washington, U.S.A.) predispose sensitive organisms to more severe acidified conditions than those of coastal and open-ocean habitats, yet the sensitive organisms persist. We suggest potential environmental factors and compensatory mechanisms that allow pelagic calcifiers to inhabit less favorable habitats and partially offset associated stressors, for instance through food supply, increased temperature, and adaptation of their life history

CITATION
Bednarsek, N., J.A. Newton, M.W. Beck, S.R. Alin, R.A. Feely, N.R. Christman, T. Klinger. 2020. Severe biological effects under present-day estuarine acidification in the seasonally variable Salish Sea. *Science of the Total Environment* DOI:10.1016/j.scitotenv.2020.142689.

SCCWRP Journal Article #1150
Full text available by request: pubrequest@sccwrp.org

Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients

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ABSTRACT
Ocean acidification (OA) along the US West Coast is intensifying faster than observed in the global ocean. This is particularly true in near shore regions (<200 m) that experience a lower buffering capacity while at the same time providing important habitats for ecologically and economically significant species. While the literature on the effects of OA from laboratory experiments is voluminous, there is little understanding of present-day OA in-situ effects on marine life. Dungeness crab (*Metacarcinus magister*) is perennially one of the most valuable commercial and recreational fisheries. We focused on establishing OA-related vulnerability of larval crustacean based on mineralogical and elemental carapace to external and internal carapace dissolution by using a combination of different methods ranging from scanning electron microscopy, energy dispersive X-ray spectroscopy, elemental mapping and X-ray diffraction. By integrating carapace features with the chemical observations and biogeochemical model hindcast, we identify the occurrence of external carapace dissolution related to the steepest Ω calcite gradients (ΔΩcal,60) in the water column. Dissolution features are observed across the carapace, pereopods (legs), and around the calcified areas surrounding neuritic canals of mechanoreceptors. The carapace dissolution is the most extensive in the coastal habitats under prolonged (1-month) long exposure, as demonstrated by the use of the model hindcast. Such dissolution has a potential to destabilize mechanoreceptors with important sensory and behavioral functions, a pathway of sensitivity to OA. Carapace dissolution is negatively related

to crab larval width, demonstrating a basis for energetic trade-offs. Using a retrospective prediction from a regression models, we estimate an 8.3% increase in external carapace dissolution over the last two decades and identified a set of affected OA-related sublethal pathways to inform future risk assessment studies of Dungeness crabs.

Citation

Bednarsek, N., R.A. Feely, M.W. Beck, S.R. Alin, S.A. Siedlecki, P. Calosi, E.L. Norton, C. Saenger, J. Strus, D. Greeley, N.P. Nezlin, M. Roethler, J.I. Spicer. 2020. Exoskeleton Dissolution With Mechanoreceptor Damage in Larval Dungeness Crab Related to Severity of Present-day Ocean Acidification Vertical Gradients. *Science of the Total Environment* DOI:10.1016/j.scitotenv.2020.136610.

SCCWRP Journal Article #1108
Full text available by request: pubrequest@sccwrp.org

Eco-physiological responses of copepods and pteropods to ocean warming and acidifcation

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Abstract

We compare physiological responses of the crustacean copepod *Calanus pacifcus* and pelagic pteropod mollusk *Limacina helicina* to ocean temperatures and pH by measuring biomarkers of oxidative stress, antioxidant defences, and the activity of the respiratory electron transport system in organisms collected on the 2016 West Coast Ocean Acidifcation cruise in the California Current System. Copepods and pteropods exhibited strong but divergent responses in the same habitat; copepods had higher oxygen-reactive absorbance capacity, glutathione-S-transferase, and total glutathione content. The ratio between reduced to oxidised glutathione was higher in copepods than in pteropods, indicating lower oxidative stress in copepods. Pteropods showed higher activities of glutathione reductase, catalase, and lipid peroxidation, indicating increased antioxidant defences and oxidative stress. Thus, the antioxidant defence system of the copepods has a greater capacity to respond to oxidative stress, while pteropods already face severe stress and show limited capacity to deal with further changes. The results suggest that copepods have higher adaptive potential, owing to their stronger vertical migration behaviour and efficient glutathione metabolism, whereas pteropods run the risk of oxidative stress and mortality under high CO_2 conditions. Our results provide a unique dataset and evidence of stress inducing mechanisms behind pteropod ocean acidification responses.

Citation

Engstrom-Ost, J., O. Glippa, R.A. Feely, J.E. Keister, S.R. Alin, B.R. Carter, A.K. McLaskey, K.A. Vuori, N. Bednarsek. 2019. Eco-physiological responses of copepods and pteropods to ocean warming and acidification. *Scientific Reports* 9:4748.

SCCWRP Journal Article #1072
Full text available online: www.sccwrp.org/publications

The shelled pteropods of the northeast Pacific Ocean (Mollusca: Heterobranchia, Pteropoda)

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Abstract

An overview of shelled pteropod species of the northeast Pacific Ocean, roughly north of 25°N and east of 160°W is presented. For the 34 recognized species (Limacinidae, Creseidae, Creseidae, Cuvierinidae, Cliidae, Cavoliniidae, Peraclidae, Clionidae) a brief description is given enabling identification. Data are based on several museum collections and the existing literature. For all species the original description and most important synonyms are referenced. Locations of type specimens are recorded as far as is known. All species are illustrated, for many species images of living specimens are included. *Cavolinia labiata* is designated type species of *Orbignyia*.

Citation

Janssen, A.W., S.L. Bush, N. Bednarsek. 2019. The shelled pteropods of the Northeastern Pacific Ocean (Mollusca: Heterobranchia, Pteropoda). *Zoosymposia* 13:305-346.

SCCWRP Journal Article #1073
Full text available online: www.sccwrp.org/publications

Relationship between shell integrity of pelagic gastropods and carbonate chemistry parameters at a Scottish Coastal Observatory monitoring site

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Abstract

Ocean acidification (OA), the anthropogenic carbon

dioxide-induced changes in seawater carbonate chemistry, is likely to have a significant impact on calcifying plankton. Most planktonic studies on OA are based on "one-off" cruises focused on offshore areas while observations from inshore waters are scarce. This study presents the first analysis on the shell integrity of pelagic gastropods (holoplanktonic pteropods and planktonic larvae of otherwise benthic species) at the Scottish Coastal Observatory monitoring site at Stonehaven on the east coast of Scotland. The shell integrity of archived pelagic gastropods specimens from 2011 to 2013 was examined using Scanning Electron Microscopy and the relationship with OA (pH and aragonite saturation, Ω_{arg}) and other environmental parameters was investigated. Evidence of shell dissolution was detected in all analysed taxa even though the seawater was supersaturated with respect to aragonite. The shell condition matched the temporal pattern observed in Ω_{arg}, with higher proportion of dissolution associated with decreasing Ω_{arg}, suggesting that the seasonality component of carbonate chemistry might affect the shell integrity of pelagic gastropods. The proportion of shell dissolution differed significantly between larvae and adult stages of pteropods, supporting the hypothesis that early-life stages would be more vulnerable to OA-induced changes. Our data also suggest that sensitivity to OA may differ even between closely related taxonomic groups. The strong interannual variability revealed by the year-to-year shell dissolution and Ω_{arg} illustrates the difficulty in assessing the plankton response to OA in the field and the value of time series studies.

CITATION

Leon, P., N. Bednarsek, P. Welsham, K. Cook, S.E. Hartman, D. Wall-Palmer, J. Hindson, K. Mackenzie, L. Webster, E. Bresnan. 2019. Relationship between shell integrity of pelagic gastropods and carbonate chemistry parameters at a Scottish Coastal Observatory monitoring site. *ICES Journal of Marine Science* DOI:10.1093/icesjms/fsz178.

SCCWRP Journal Article #1095
Full text available online: www.sccwrp.org/publications

Large contribution of pteropods to shallow $CaCO_3$ export

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ABSTRACT

The literature on the relative contributions of pelagic calcifying taxa to the global ocean export of $CaCO_3$ is divided. Studies based on deep sediment trap data tend to argue that either foraminifers or coccolithophores, both calcite producers, dominate export. However, the compilations of biomass observations for pteropods, coccolithophores, and foraminifers instead show that pteropods dominate the global ocean calcifier biomass and therefore likely also carbonate export. Here we present a new global ocean biogeochemical model that explicitly represents these three groups of pelagic calcifiers. We synthesize databases of the physiology of the three groups to parameterize the model and then tune the unconstrained parameters to reproduce the observations of calcifier biomass and $CaCO_3$ export. The model can reproduce both these observational databases; however, substantial dissolution of aragonite above the aragonite saturation horizon is required to do so. We estimate a contribution of pteropods to shallow (100 m) export of $CaCO_3$ of at least 33% and to pelagic calcification of up to 89%. The high production-high dissolution configuration that shows closest agreement with all the observations has a $CaCO_3$ production of 4.7 Pg C/year but $CaCO_3$ export at 100 m of only 0.6 Pg C/year.

CITATION

Buitenhuis, E.T., C.L. Quere, N. Bednarsek, R. Schiebel. 2019. Large Contribution of Pteropods to Shallow $CaCO_3$ Export. *Global Biogeochemical Cycles* 33:458-468.

SCCWRP Journal Article #1071
Full text available online: www.sccwrp.org/publications

Enhancing California's ocean acidification and hypoxia monitoring network

Stephen Weisberg[1], Francis Chan[2], Jim Barry[3], Alexandria Boehm[4], Shallin Busch[5], Sarah Cooley[6], Richard Feely[7], Lisa Levin[8]

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CITATION

Weisberg, S.B., F. Chan, J. Barry, A. Boehm, S. Busch, S. Cooley, R. Feely, L. Levin. 2020. Enhancing California's Ocean Acidification and Hypoxia Monitoring Network. Technical Report 1137. Ocean Protection Council. Sacramento, CA.

SCCWRP Technical Report #1137
Full text available online: www.sccwrp.org/publications

Vulnerability of stream biological communities in Los Angeles and Ventura Counties to climate change induced alterations of flow and temperature

Jennifer B. Taylor[1], Eric D. Stein[1], Marcus Beck[1], Kelly Flint[2], Alicia Kinoshita[2]

[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[2]*San Diego State University, San Diego, CA*

CITATION

Taylor, J., E.D. Stein, M. Beck, K. Flint, A. Kinoshita. 2019. Vulnerability of Stream Biological Communities in Los Angeles and Ventura Counties to Climate Change Induced Alterations of Flow and Temperature. Technical Report 1084. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1084
Full text available online: www.sccwrp.org/publications

Aquatic resource type conversion evaluation framework

Eric D. Stein[1], Jeffrey S. Brown[1]

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CITATION

Stein, E.D., J.S. Brown. 2020. Aquatic Resource Type Conversion Evaluation Framework. Technical Report 1110. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1110
Full text available online: www.sccwrp.org/publications

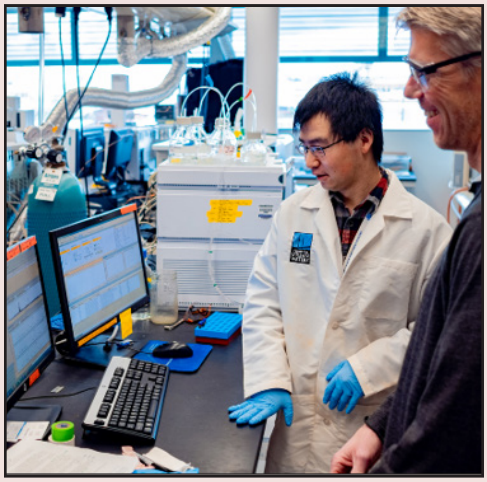
Non-targeted analysis used to help identify toxic chemicals

A team of researchers that includes SCCWRP has completed a high-profile, first-of-its-kind case study demonstrating how to use an analytical method known as non-targeted chemical analysis to help identify specific chemicals in complex environmental mixtures as the cause of observed toxicity.

The multi-year investigation, which focused on mass seasonal deaths of coho salmon in the Pacific Northwest, illustrates the power and potential of using non-targeted chemical analysis to help solve some of the most vexing management challenges in environmental toxicology.

During the study, which was published in 2020 by the journal *Science*, researchers used non-targeted chemical analysis to zero in on a specific, previously unknown chemical responsible for the coho salmon toxicity in the Pacific Northwest. SCCWRP has been working to advance non-targeted chemical analysis for the past decade.

The chemical responsible for the Pacific Northwest salmon die-offs – 6PPD-quinone, a derivative of a ubiquitous preservative used in tire manufacturing – was not on researchers' radar at the beginning of the study, underscoring the value of using non-targeted chemical analysis in tandem with more established chemistry and toxicology methods to identify specific toxicity culprits.



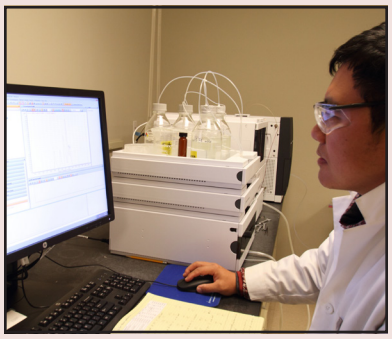
Researchers at the University of Washington examine data generated by non-targeted chemical analysis. A research team that includes SCCWRP found that this technology can be a key asset in identifying a specific unknown chemical as the cause of observed toxicity in aquatic environments.

Bioanalytical assays, non-targeted analysis used to assess Bight '18 sediment

SCCWRP and its partners have completed screening Southern California Bight sediment samples for bioactive chemical contaminants using bioanalytical screening and non-targeted chemical analysis methods.

The work – completed in 2020 using samples collected via the Southern California Bight 2018 Regional Monitoring Program – is part of an ongoing effort to determine whether this pair of novel screening methods could be used to help identify chemicals suspected of causing adverse effects in aquatic life. The pair of methods is envisioned as a cost-effective complement to traditional chemistry and toxicology analysis methods.

During the study – which marked the first time the methods have been applied on a regional scale – researchers found that bioanalytical cell assays were effective at identifying Bight sites where sediment quality is impacted. Subsequent non-targeted chemistry analyses, meanwhile, were effective at identifying contaminants suspected of being responsible for the observed bioactivity.



SCCWRP's Dr. Bowen Du analyzes data to look for evidence of bioactivity in chemical contamination. Researchers have been working to detect bioactive contaminants using non-targeted chemical analysis in tandem with bioanalytical cell assays.

Researchers' goal is to determine whether the sites identified as impacted correlate with the sediment contamination impacts that Bight '18 identified using traditional methods.

Guidance, training developed for how to use bioanalytical assays to screen for contaminants

SCCWRP has partnered with the National Water Research Institute (NWRI) to co-author guidance and offer training to California's water recycling community on how to incorporate bioanalytical screening technology into routine water-quality monitoring.

The guidance, developed in 2019 by a seven-member NWRI panel that includes SCCWRP, will offer best-practice recommendations for using bioanalytical cell assays to screen certain types of recycled water for bioactive contaminants.

The State Water Board last year adopted a policy amendment requiring bioanalytical screenings to be incorporated into monitoring of recycled water for potable reuse. During a three-year trial period that started in 2020, water recycling agencies in California will screen for bioactive contaminants using two types of bioanalytical assays – the estrogen receptor assay and the aryl hydrocarbon receptor assay.

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A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon

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Abstract

In U.S. Pacific Northwest coho salmon (*Oncorhynchus kisutch*), stormwater exposure annually causes unexplained acute mortality when adult salmon migrate to urban creeks to reproduce. By investigating this phenomenon, we identified a highly toxic quinone transformation product of N-(1,3-dimethylbutyl)-N′-phenyl-p-phenylenediamine (6PPD), a globally ubiquitous tire rubber antioxidant. Retrospective analysis of representative roadway runoff and stormwater-affected creeks of the U.S. West Coast indicated widespread occurrence of 6PPD-quinone (<0.3 to 19 micrograms per liter) at toxic concentrations (median lethal concentration of 0.8 ± 0.16 micrograms per liter). These results reveal unanticipated risks of 6PPD antioxidants to an aquatic species and imply toxicological relevance for dissipated tire rubber residues.

Citation

Tian, Z., H. Zhao, K.T. Peter, M. Gonzalez, J. Wetzel, C. Wu, X. Hu, J. Prat, E. Mudrock, R. Hettinger, A.E. Cortina, R.G. Biswas, F.V.C. Kock, R. Soong, A. Jenne, B. Du, F. Hou, H. He, R. Lundeen, A. Gilbreath, R. Sutton, N.L. Scholz, J.W. Davis, M.C. Dodd, A. Simpson, J.K. McIntyre, E.P. Kolodziej. 2020. A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. *Science* 371:185-189.

SCCWRP Journal Article #1162
Full text available by request: pubrequest@sccwrp.org

Developing unique nontarget high-resolution mass spectrometry signatures to track contaminant sources in urban waters

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Abstract

Diffuse pollution in urban receiving waters often adversely impacts both humans and ecosystems. Identifying such pollution sources is challenging and limits the effectiveness of management actions intended to reduce risk. Here, we evaluated the use of nontarget analysis via high-resolution mass spectrometry (HRMS) to develop chemical fingerprints/signatures for source tracking. Specifically, we applied nontarget HRMS to characterize and differentiate two urban chemical sources: roadway runoff and wastewater influent. We isolated 112 and 598 nontarget compounds (both known and unidentified chemicals) that co-occurred in all roadway runoff and wastewater influent samples, respectively, and were unique relative to other sampled sources. For example, methamphetamine, often considered wastewater derived, was detected in all samples, implying that individual wastewater indicators may lack sufficient specificity in urban receiving waters impacted by multiple sources. Hierarchical cluster analysis differentiated source types, and normalized abundance profiling prioritized nontarget compounds with consistent relative abundance patterns across field sites for a given source. Hexa (methoxymethyl) melamine, 1,3-diphenylguanidine, and polyethylene glycols co-occurred in roadway runoff across geographic areas and traffic intensities, supporting continued development of a universal roadway runoff fingerprint based on ubiquitous compounds. This study provides a proof-of-concept for isolating nontarget source fingerprints to track diffuse contamination in urban receiving waters.

Citation

Du, B., Z. Tian, K.T. Peter, E.P. Kolodziej, C.S. Wong. 2020. Developing Unique Nontarget High-Resolution Mass Spectrometry Signatures to Track Contaminant Sources in Urban Waters. *Environmental Science & Technology Letters* 7:923-930.

SCCWRP Journal Article #1148
Full text available by request: pubrequest@sccwrp.org

Evaluating the estrogenicity of an effluent-dominated river in California, USA: comparisons of *in vitro* and *in vivo* bioassays

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Abstract

Many pollutants cause endocrine disruption in aquatic organisms. While studies of the direct effects of toxicants on exposed organisms are commonplace, little is known about the potential for toxicant exposures in a parental (F0) generation to affect unexposed F1 or F2 generations (multigenerational

and transgenerational effects, respectively), particularly in estuarine fishes. To investigate this possibility, we exposed inland silversides (*Menidia beryllina*) to environmentally relevant (low ng/L) concentrations of ethinylestradiol, bifenthrin, trenbolone, and levonorgestrel from 8 hpf to 21 dph. We then measured development, immune response, reproduction, gene expression, and DNA methylation for two subsequent generations following the exposure. Larval exposure (F0) to each compound resulted in negative effects in the F0 and F1 generations, and for ethinylestradiol and levonorgestrel, the F2 also. The specific endpoints that were responsive to exposure in each generation varied, but included increased incidence of larval deformities, reduced larval growth and survival, impaired immune function, skewed sex ratios, ovarian atresia, reduced egg production, and altered gene expression. Additionally, exposed fish exhibited differences in DNA methylation in selected genes, across all three generations, indicating epigenetic transfer of effects. These findings suggest that assessments across multiple generations are key to determining the full magnitude of adverse effects from contaminant exposure in early life.

CITATION

Harraka, G.T., J.T. Magnuson, B. Du, C.S. Wong, K. Maruya, D. Schlenk. 2020. Evaluating the estrogenicity of an effluent-dominated river in California, USA: Comparisons of *in vitro* and *in vivo* bioassays. *Science of the Total Environment* 758:143965.

SCCWRP Journal Article #1163
Full text available by request: pubrequest@sccwrp.org

Early life exposure to environmentally relevant levels of endocrine disruptors drive multigenerational and transgenerational epigenetic changes in a fish model

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ABSTRACT

The inland silverside, *Menidia beryllina*, is a euryhaline fish and a model organism in ecotoxicology. We previously showed that exposure to picomolar (ng/L) levels of endocrine disrupting chemicals (EDCs) can cause a variety of effects in *M. beryllina*, from changes in gene expression to phenotypic alterations. Here we explore the potential for early life exposure to EDCs to modify the epigenome in silversides, with a focus on multi- and transgenerational effects. EDCs included contaminants of emerging concern (the pyrethroid insecticide bifenthrin and the synthetic progestin levonorgestrel), as well as a commonly detected synthetic estrogen (ethinylestradiol), and a synthetic androgen (trenbolone) at exposure levels ranging from 3 to 10 ng/L. In a multigenerational experiment, we exposed parental silversides to EDCs from fertilization until 21 days post hatch (dph). Then we assessed DNA methylation patterns for three generations (F0, F1, and F2) in whole body larval fish using reduced representation bisulfite sequencing (RRBS). We found significant ($\alpha = 0.05$) differences in promoter and/or gene body methylation in treatment fish relative to controls for all EDCs and all generations indicating that both multigenerational (F1) and transgenerational (F2) effects that were caused by strict inheritance of DNA methylation alterations and the dysregulation of epigenetic control mechanisms. Using gene ontology and pathway analyses, we found enrichment in biological processes and pathways representative of growth and development, immune function, reproduction, pigmentation, epigenetic regulation, stress response and repair (including pathways important in carcinogenesis). Further, we found that a subset of potentially EDC responsive genes (EDCRGs) were differentially methylated across all treatments and generations and included hormone receptors, genes involved in steroidogenesis, prostaglandin synthesis, sexual development, DNA methylation, protein metabolism and synthesis, cell signaling, and neurodevelopment. The analysis of EDCRGs provided additional evidence that differential methylation is inherited by the offspring of EDC-treated animals, sometimes in the F2 generation that was never exposed. These findings show that low, environmentally relevant levels of EDCs can cause altered methylation in genes that are functionally relevant to impaired phenotypes documented in EDC-exposed animals and that EDC exposure has the potential to affect epigenetic regulation in future generations of fish that have never been exposed.

CITATION

Major, K.M., B.M. DeCourten, J. Li, M. Britton, M.L. Settles, A.C. Mehinto, R.E. Connon, S.M. Brander. 2020. Early Life Exposure to Environmentally Relevant Levels of Endocrine Disruptors Drive Multigenerational and Transgenerational Epigenetic Changes in a Fish Model. *Frontiers in Marine Science* DOI:10.3389/fmars.2020.00471.

SCCWRP Journal Article #1128
Full text available online: www.sccwrp.org/publications

Multigenerational and transgenerational effects of environmentally relevant concentrations of endocrine disruptors in an estuarine fish model

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ABSTRACT

Many pollutants cause endocrine disruption in aquatic organisms. While studies of the direct effects of toxicants on exposed organisms are commonplace, little is known about the potential for toxicant exposures in a parental (F0) generation to affect unexposed F1 or F2 generations (multigenerational and transgenerational effects, respectively), particularly in estuarine fishes. To investigate this possibility, we exposed inland silversides (*Menidia beryllina*) to environmentally relevant (low ng/L) concentrations of ethinylestradiol, bifenthrin, trenbolone, and levonorgestrel from 8 hpf to 21 dph. We then measured development, immune response, reproduction, gene expression, and DNA methylation for two subsequent generations following the exposure. Larval exposure (F0) to each compound resulted in negative effects in the F0 and F1 generations, and for ethinylestradiol and levonorgestrel, the F2 also. The specific endpoints that were responsive to exposure in each generation varied, but included increased incidence of larval deformities, reduced larval growth and survival, impaired immune function, skewed sex ratios, ovarian atresia, reduced egg production, and altered gene expression. Additionally, exposed fish exhibited differences in DNA methylation in selected genes, across all three generations, indicating epigenetic transfer of effects. These findings suggest that assessments across multiple generations are key to determining the full magnitude of adverse effects from contaminant exposure in early life.

CITATION

DeCourten, B.M., J.P. Forbes, H.K. Roark, N.P. Burns, K.M. Major, J.W. White, J. Li, A.C. Mehinto, R.E. Connon, S.M. Brander. 2020. Multigenerational and Transgenerational Effects of Environmentally Relevant Concentrations of Endocrine Disruptors in an Estuarine Fish Model. *Environmental Science & Technology* DOI:10.1021/acs.est.0c02892.

SCCWRP Journal Article #1157
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Organochlorine pesticides: Agrochemicals with potent endocrine disrupting properties in fish

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ABSTRACT

Organochlorine pesticides (OCPs) are persistent environmental contaminants that act as endocrine disruptors and organ system toxicants. These pesticides (e.g. dichlorodiphenyltrichloroethane (DDT), dieldrin, toxaphene, among others) are ranked as some of the most concerning chemicals for human health. These pesticides (1) act as teratogens, (2) are neuroendocrine disruptors, (3) suppress the immune and reproductive systems, and (4) dysregulate lipids and metabolism. Using a computational approach, we revealed enriched endocrine-related pathways in the Comparative Toxicogenomics Database sensitive to this chemical class, and these included reproduction (gonadotropins, estradiol, androgen, steroid biosynthesis, oxytocin), thyroid hormone, and insulin. Insight from the Tox21 and ToxCast programs confirm that these agrochemicals activate estrogen receptors, androgen receptors, and retinoic acid receptors with relatively high affinity, although differences exist in their potency. We propose an adverse outcome pathway for OCPs toxicity in the fish testis as a novel contribution to further understanding of OCP-induced toxicity. Organochlorine pesticides, due to their persistence and high toxicity to aquatic and terrestrial wildlife as well as humans, remain significant agrochemicals of concern.

CITATION

Martyniuk, C.J., A.C. Mehinto, N.D. Denslow. 2020. Organochlorine pesticides: Agrochemicals with potent endocrinedisrupting properties in fish. *Molecular and Cellular Endocrinology* DOI:10.1016/j.mce.2020.110764.

SCCWRP Journal Article #1124
Full text available by request: pubrequest@sccwrp.org

Transcriptome and physiological effects of toxaphene on the livergonad reproductive axis in male and female largemouth bass (*Micropterus salmoides*)

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ABSTRACT

Toxaphene is an organochlorine pesticide and environmental contaminant that is concerning due to its atmospheric transport and persistence in soil. In Florida, toxaphene and other organochlorine pesticides were used heavily in agriculture on the north shore of Lake Apopka and they are still detectable in soil. Wild largemouth bass that inhabit the lake and the marshes along the north shore have been exposed to a variety of organochlorine pesticides including dieldrin, methoxychlor, and p,p′-DDE, among others. While these other organochlorine pesticides have been studied for their endocrine disrupting effects in largemouth bass, there is little information for toxaphene. In this study, male and female largemouth bass were given food containing 50 mg/kg toxaphene for almost 3 months, to achieve tissue levels similar to those found in fish at Lake Apopka. Sex-specific toxicity was then evaluated by measuring various reproductive endpoints and transcriptomic changes. In females, gonadosomatic index showed a trend towards reduction ($p = 0.051$) and

plasma vitellogenin was reduced by ~40% relative to controls. However plasma levels of 17β-estradiol and testosterone were not perturbed by toxaphene exposure. These data suggest that toxaphene does not act as a weak estrogen as many other organochlorine pesticides do, but rather appears to be acting as an antiestrogen in female fish. There were no obvious changes in the gonadosomatic index and plasma hormones in male bass. However, ex vivo explant experiments revealed that toxaphene prevented human chorionic gonadotropin-stimulated testosterone production in the testis. This suggested that toxaphene had anti-androgenic effects in males. Subsequent transcriptomic analyses of the testis revealed that androgen receptor/beta-2-microglobulin signaling was up-regulated while insulin-related pathways were suppressed with toxaphene, which could be interpreted as a compensatory response to androgen suppression. In the male liver, the transcriptome analysis revealed an overwhelming suppression in immunerelated signaling cascades (e.g. lectin-like receptor and ITSM-Containing Receptor signaling, CD16/CD14 Proinflammatory Monocyte Activation, and CD38/CD3-JUN/FOS/NF-kB Signaling in T-cell Proliferation). Overall, this study showed that toxaphene induced sex-specific effects. The transcriptomic and physiological responses observed can contribute to the development of adverse outcome pathways for toxaphene exposure in fish.

Citation

Martyniuk, C.J., A.C. Mehinto, R.C. Colli-Dula, K.J. Kroll, N.J. Doperalski, D.S. Barber, N.D. Denslow. 2020. Transcriptome and physiological effects of toxaphene on the liver-gonad reproductive axis in male and female largemouth bass (Micropterus salmoides). *Comparative Biochemistry and Physiology - Part D* DOI:10.1016/j.cbd.2020.100746.

SCCWRP Journal Article #1156
Full text available by request: pubrequest@sccwrp.org

Fiproles as a proxy for ecological risk assessment of mixture of fipronil and its degradates in effluent-dominated surface waters

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Abstract

Environmental risk assessment of complex chemical mixtures has increasingly been prioritized as a management goal, especially in the regulatory sector. Although fipronil and its three degradates (-sulfone, -sulfide and -desulfinyl) have been frequently quantified in waterways, little information is available about the likelihood and magnitude of ecological risk posed by these chemical mixtures – collectively known as fiproles in surface water. In the present study, a probabilistic risk assessment of mixtures of fipronil and its three degradates was conducted for three effluent-dominated southern California rivers: Los Angeles River (LAR), San Gabriel River (SGR) and Santa Clara River (SCR), California, USA. The assessments, which used fiproles as an integrated proxy, were based on three levels of toxicity endpoints: median lethal concentration (LC50), half-maximal effective concentration (EC50), and lowest observed effect concentration (LOEC), to gain comprehensive assessment information. Probabilistic approaches based on species sensitivity distribution (SSD) and exposure concentration distribution (ECD) were developed with the log- logistic model by pooling the toxicity and occurrence data, respectively. The 5th percentile hazardous concentrations (HC5s) were calculated to be at low parts per billion levels, enabling these values to be used to estimate the chemical-specific benchmarks for components that lack ecotoxicity data. The single substance potentially affected fraction (ssPAF) of fiproles revealed risk levels for the three rivers in descending order: LAR ≥ SGR > SCR. The overall risk probability estimated from the joint probability curve (JPC) by Monte Carlo simulation was 1.13 ± 0.20% (LC50), 9.31 ± 1.46% (EC50), and 6.58 ± 1.43% (LOEC) for the three rivers collectively. These results derived from the fiproles indicates that fipronil and its degradates pose risks to the aquatic organisms in the surface water of the three rivers. The present study provides a methodology for the use of a proxy in the risk assessment of chemical mixtures.

Citation

Lao, W. 2020. Fiproles as a proxy for ecological risk assessment of mixture of fipronil and its degradates in effluent-dominated surface waters. *Water Research* DOI:10.1016/j.watres.2020.116510.

SCCWRP Journal Article #1149
Full text available by request: pubrequest@sccwrp.org

An exponential model based new approach for correcting aqueous concentrations of hydrophobic organic chemicals measured by polyethylene passive samplers

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Abstract

Although low density polyethylene (PE) passive samplers show promise for the measurement of aqueous phase hydrophobic organic chemicals (HOCs), the lack of a practical and unsophisticated approach to account for non-equilibrium exposure conditions has impeded widespread acceptance and thus application *in situ*. The goal of this study was to develop a streamlined approach based on an exponential model and a convection mass transfer principle for correcting aqueous concentrations for HOCs deduced by PE samplers under non-equilibrium conditions. First, uptake rate constants (k_1), elimination rate constants (k_2), and seawater-PE equilibrium partition coefficients (K_{PEW}s) were determined in laboratory experiments for a diverse suite of HOCs with logK_{ow} range of 3.4–8.3. Linear relationships between log k_2 and logK_{ow},

and between log K_{PEW} and logK_{ow} were established. Second, PE samplers pre-loaded with ^{13}C-labeled performance reference compounds (PRCs) were deployed in the ocean to determine their k_2 *in situ*. By applying boundary layer and convection mass transfer theories, ratio (C) of k_2 values in field and laboratory exposures was estimated. This C value was demonstrated a constant that was only determined by water velocities and widths of PE strips. A generic equation with C and logK_{ow} as parameters was eventually established for extrapolation of non-equilibrium correction factors for the water boundary layer-controlled HOCs. Characterizing the hydrodynamic conditions indicated the sampler configuration and mooring mode should aim at sustaining laminar flow on the PE surface for optimal mass transfer. The PE estimates corrected using this novel approach possessed high accuracy and acceptable precision, and can be suited for a broad spectrum of HOCs. The presented method should facilitate routine utilization of the PE samplers.

Citation

Lao, W., K.A. Maruya, D. Tsukada. 2019. An exponential model based new approach for correcting aqueous concentrations of hydrophobic organic chemicals measured by polyethylene passive samplers. *Science of the Total Environment* 646:11-18.

SCCWRP Journal Article #1044
Full text available by request: pubrequest@sccwrp.org

Impact of passive sampler protection apparatus on sediment porewater profiles of hydrophobic organic compounds

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Abstract

Passive sampling techniques have been widely used to determine the dissolved concentration profiles of hydrophobic organic compounds (HOCs) in sediment porewater. However, the effects of having a protection for the passive sampler on profiling HOCs concentrations in sediment porewater, especially in deep sediment, have remained unclear. To address this issue, low density polyethylene passive samplers with and without protectors, which consisted of glass fiber filter and porous stainless steel shield, were simultaneously deployed in sediment of the Dongjiang River, South China. The results showed that the protectors retarded the dissipation of performance reference compounds (PRCs) from the sampler by a factor of 2–9. The protectors seemed to exert a negligible effect on the measured concentrations of PAHs, BDE-47, and BDE-99 in surficial sediment porewater (0–14 cm depth) from both samplers. However, the sediment porewater concentration profiles of PAHs and BDE-47 from the sampler with protectors were in agreement with those normalized by dry weight in deep sediment (16–34 cm depth), indicating that a diffusion layer established by the protectors may minimize the probability of local depletion of the target analytes in deep sediment. In addition, the log K_{oc} values of PAHs, BDE-47, and BDE-99 exhibited a slight increasing trend with sediment depth. This finding suggested that *in situ* passive sampling techniques could be a feasible tool in determining the site-specific log K_{oc} values of HOCs at different sediment depths.

Citation

Wu, L., R. Wang, C.L. Huang, C.C. Wu, C.S. Wong, L.J. Bao, E.Y. Zeng. 2020. Impact of passive sampler protection apparatus on sediment porewater profiles of hydrophobic organic compounds. *Chemosphere* DOI:10.1016/j.chemosphere.2020.126534.

SCCWRP Journal Article #1119
Full text available by request: pubrequest@sccwrp.org

Measuring bioconcentration factors of sediment-associated fipronil in *Lumbriculus variegatus* using passive sampling techniques

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[3]Southern California Coast Water Research Project, Costa Mesa, CA

Abstract

Fipronil and its degradates have been detected ubiquitously in aquatic environment worldwide, yet little is known about its bioaccumulation potential. The goal of the present study was to measure bioconcentration factor (BCF) of sediment-associated fipronil in a benthic invertebrate, *Lumbriculus variegatus* using passive sampling techniques. Three passive samplers including polymethyl methacrylate (PMMA) film, poly(dimethylsiloxane) fiber and polyacrylate fiber were evaluated. PMMA film was identified as the preferred method and was applied to determine fipronil log K_{OC} (3.77 ± 0.04). BCF of sediment-associated fipronil in *L. variegatus* was obtained through measuring freely dissolved concentration (C_{free}). Because fipronil degraded in sediment, time weighted average (TWA) C_{free} was estimated for calculating BCF_{TWA} (1855 ± 293 mL/g lipid). Fipronil BCF was also measured in a water-only bioaccumulation test of *L. variegatus* under constant exposure condition. This BCF value (1892 ± 76 mL/g lipid) was comparable with the BCF_{TWA}, validating effectiveness of the passive sampling method for the measurement of sediment C_{free}. Fipronil was bioaccumulative in *L. variegatus* according to the USEPA's criteria. The combination of C_{free} and TWA concentration measurements was demonstrated to properly determine BCF value for moderately hydrophobic and degradable chemicals in sediment.

CITATION

Wang, S., W. Lao, H. Li, J. You. 2020. Measuring bioconcentration factors of sediment-associated fipronil in Lumbriculus variegatus using passive sampling techniques. *Journal of Hazardous Materials* DOI:10.1016/j.jhazmat.2020.122420.

SCCWRP Journal Article #1112
Full text available by request: pubrequest@sccwrp.org

Calibration of organic-diffusive gradients in thin films (o-DGT) passive samplers for perfluorinated alkyl acids in water

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ABSTRACT

The application of the organic-diffusive gradients in thin films (o-DGT) passive sampling technique for the monitoring of per- and polyfluoroalkyl substances (PFAS) in the environment is still limited. Six common PFAS with different chain lengths were evaluated in water by o-DGT. Measured diffusion co-efficients (D) in agarose and polyacrylamide diffusive gels ranged from 4.55-8.63 * 10^{-6} cm^2 s^{-1} and 3.85-7.00 * 10^{-6} cm^2 s^{-1} at 23 °C, respectively. Experimental sampling rates (Rs) for both agarose- and polyacrylamide-WAX sampler configurations were within 22% relative error of D-based Rs for four of the PFAS. Larger differences for perfluorobutanesulfonic acid (PFBS) and perfluoroundecanoic acid (PFUnDA) ranged from 36% to 56%. In general, *in-situ* Rs can be predicted using measured D-values for per-fluorinated alkyl acids. The mass accumulation of six PFAS in two o-DGT configurations was linear over 21 days ($R^2 \geq 0.97$). Diffusion and uptake of o-DGT depended on the gel type and specific PFAS. Field demonstrations of o-DGT with WAX and HLB binding gels and polyacrylamide diffusive gels (not prone to biodegradation) found 0.3-19.5 ng L^{-1} of PFAS in rivers near industrial areas around Guangzhou and Foshan, China, with no apparent differences between the two co-deployed samplers. This study demonstrates that the configurations of o-DGT tested provide a cost-effective monitoring tool for measuring perfluorinated alkyl acids in aquatic systems, in particular the four PFAS for which reasonable correlations were observed.

CITATION

Wang, P.F., J.K. Challis, K.H. Luong, T.C. Vera, C.S. Wong. 2020. Calibration of organic-diffusive gradients in thin films (o-DGT) passive samplers for perfluorinated alkyl acids in water. *Chemosphere* DOI:10.1016/j.chemosphere.2020.128325.

SCCWRP Journal Article #1146
Full text available by request: pubrequest@sccwrp.org

The unknowns of microplastics: We cannot understand what we cannot measure

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ABSTRACT

The issue of microplastics was first reported in the 1970s when researchers found small pieces of plastic floating in the middle of the North Atlantic. Decades later, Richard Thompson coined the term “microplastics” to refer to pieces of plastic debris <5 mm in size, which sparked research into this area by oceanographers, marine ecologists, and marine biologists. However, we know now that microplastics are not limited to our oceans but contaminate marine, freshwater and terrestrial ecosystems and travel from one ecosystem compartment to another via air, water, and biota.

CITATION

Rochman, C.M., S.B. Weisberg, S.L. Moore, A. Whitley. 2020. The Unknowns of Microplastics: We cannot understand what we cannot measure. *Applied Spectroscopy* 74:966-967.

SCCWRP Journal Article #1166
Full text available by request: pubrequest@sccwrp.org

Steps scientists can take to inform aquatic microplastics management: A perspective informed by the California experience

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ABSTRACT

Recent evidence suggests that microplastic particles are pervasive and potentially of great risk to both animal and human health. The California legislature has responded to this information by enacting two new bills that require quantification of microplastics in various media and development of new management strategies to address microplastic pollution. However, there are several scientific gaps that impede the development and implementation of necessary management strategies to address microplastic pollution. In this paper, we use the California experience as a case study to provide perspective on those science gaps, the current barriers to science affecting management, and the actions scientists can take to best ensure their efforts are of greatest value to policymakers and the management community

CITATION

Wyer, H., D. Polhemus, S.L. Moore, S.B. Weisberg, S. Coffin, C.M. Rochman. 2020. Steps Scientists Can Take to Inform Aquatic Microplastics Management: A Perspective Informed by the California Experience. *Applied Spectroscopy* 74:971-975.

SCCWRP Journal Article #1145
Full text available by request: pubrequest@sccwrp.org

Photodegradation of bitumen-derived organics in oil sands process-affected water

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ABSTRACT

The chemical composition of water-soluble organics in oil sands process-affected water (OSPW) is primarily composed of natural constituents of bitumen that are solubilized and concentrated during aqueous extraction of oil sands. OSPW organics are persistent and acutely toxic, and a leading remediation strategy is long-term ageing in end-pit lakes, despite limited data available on its photochemical fate. Here, direct photolysis of whole OSPW, or of its constituent fractions, was examined at environmentally relevant wavelengths (>290 nm) in bench-top studies. Changes in the chemical profiles of whole OSPW, acid- (AEO), and base extractable organics (BEO) were characterized by liquid chromatography with ultra-high resolution mass spectrometry in negative (-) and positive (+) ionization modes. Following 18 d of irradiation, photolysis reduced the total ion intensity in all samples in both modes. The most photo-labile species included the O_2^-, O_3^-, O_4^-, O_2S^-, and O_4S^- chemical classes, which were depleted in whole OSPW by 93–100% after only 5 d. In positive mode, detected species were more recalcitrant than those detected in negative mode, with an average reduction across all heteroatomic classes of 75 +/- 11.0% after 18 d. Estimated environmental half-lives for heteroatomic classes ranged from 57 d (O_4S^-) to 545 d (O_3N^+), with a greater recalcitrance for classes detected in positive mode compared to negative mode. Under field conditions in end-pit lakes, natural photolysis may be an important mechanism for effective OSPW remediation, and we suggest that future end-pit lakes be shallow to maximize light penetration and natural photolysis in ageing OSPW.

CITATION

Challis, J.K., A. Parajas, J.C. Anderson, E. Asiedu, J.W. Martin, C.S. Wong, M.S. Ross. 2020. Photodegradation of bitumen-derived organics in oil sands process-affected water. *Environmental Science: Processes & Impacts* 22:1243-1255.

SCCWRP Journal Article #1121
Full text available by request: pubrequest@sccwrp.org

Evaluation of cold-weather wastewater nitrification technology for removal of polar chemicals of emerging concern from rural Manitoba wastewaters

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ABSTRACT

Aerated lagoons, typically used by small communities, often provide limited removal of wastewater nutrients. Given increasingly stringent wastewater standards, it is imperative that effective, but economical and easy-to-operate, treatment technologies be developed. The Submerged Attached Growth Reactor (SAGR®) is a treatment process developed to perform nitrification near freezing temperatures. Previous tests on full-scale installations have shown that SAGR could consistently remove ammonia to below current Canadian standards and provide additional total suspended solids and biochemical oxygen demand removal. In this study, we evaluated removal of polar chemicals of emerging concern (CECs), including pharmaceuticals, personal care products, and pesticides, at SAGR installations in two Manitoba First Nations communities (MCN and LPFN) under cold winter conditions. Both showed some removal of diclofenac, naproxen, clarithromycin, metoprolol, and trimethoprim, likely by biotransformation. Average naproxen removal was 21% (2.53×10^3 ng L^{-1}) in MCN and 64% (1.58×10^3 ng L^{-1}) in LPFN. Atenolol was well-removed by SAGR, by 80% on average (range of 64%-94%). Clarithromycin, metoprolol, and trimethoprim removal was similar within and between systems, ranging from 54% to 76% ($30.8 - 3.07 \times 10^2$ ng L^{-1} removed). Carbamazepine was detected in nearly all samples, but was not well removed, consistent with other treatment studies. Overall, results showed that SAGR technology could moderately remove CECs, while providing the designed treatment performance for other parameters. This work will help to improve our understanding of wastewater treatment in small and/or remote communities with limited infrastructure and challenging cold-weather conditions.

CITATION

Anderson, J.C., P. Jabari, A. Parajas, E. Loeb, K.H. Luong, A. Vahedi, C.S. Wong. 2020. Evaluation of cold-weather wastewater nitrification technology for removal of polar chemicals of emerging concern from rural Manitoba wastewaters. *Chemosphere* DOI:10.1016/j.chemosphere.2020.126711.

SCCWRP Journal Article #1120
Full text available by request: pubrequest@sccwrp.org

In situ kinetics of human pharmaceutical conjugates and the impact of transformation, deconjugation, and sorption on persistence in wastewater batch bioreactors

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ABSTRACT

The fate of selected common pharmaceuticals and four of their major conjugates in wastewater batch bioreactors was evaluated to determine how treatment plant parameters such as addition of air, and the presence of waste activated sludge (WAS) could influence the removal of parent compounds and conjugates. Under a realistic hydraulic residence time (HRT) for each treatment sub-process of approximately 2 h, acetaminophen and its sulfate metabolite were both rapidly degraded (>99%). Propranolol was sulfated and concurrently removed. Deconjugation of N-acetylsulfamethoxazole and sulfamethoxazole-glucuronide contributed to increases of the parent sulfamethoxazole. Thyroxine was resistant to degradation, while thyroxine-glucuronide was rapidly deconjugated (>90% in <2 h). In the absence of WAS, sorption to suspended solids was another major removal mechanism for acetaminophen, propranolol, sulfamethoxazole, and thyroxine. However, with WAS, concentrations associated with suspended solids decreased for all analytes within 24 h. These results indicate that both conjugation and back-transformation are compound-specific and dependent on parameters such as HRT, addition of microbial content, and suspended solids levels. Therefore, conjugation-deconjugation processes may strongly influence the speciation of pharmaceuticals and their fate in wastewater treatment plant effluents.

CITATION

Brown, A.K., J. Ackerman, N. Cicek, C.S. Wong. 2020. *In situ* kinetics of human pharmaceutical conjugates and the impact of transformation, deconjugation, and sorption on persistence in wastewater batch bioreactors. *Environmental Pollution* DOI:10.1016/j.envpol.2020.114852.

SCCWRP Journal Article #1125
Full text available by request: pubrequest@sccwrp.org

Apex marine predators and ocean health: Proactive screening of halogenated organic contaminants reveals ecosystem indicator species

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

Despite decades-long bans on the production and use of certain chemicals, many halogenated organic compounds (HOCs) are persistent and can bioaccumulate in the marine environment with the potential to cause physiological harm to marine fauna. High lipid-rich tissue (e.g., marine mammal blubber) functions as a reservoir for HOCs, and selecting ideal indicator species is a priority for retrospective and proactive screening efforts. We selected five marine mammal species as possible indicators for the Southern California Bight (SCB) and applied a non-targeted analytical method paired with an automated data reduction strategy to catalog a broad range of known, known but unexpected, and unknown compounds in their blubber. A total of 194 HOCs were detected across the study species (n = 25 individuals), 81% of which are not routinely monitored, including 30 halogenated natural products and 45 compounds of unknown structure and origin. The cetacean species (long-beaked common dolphin, short-beaked common dolphin, and Risso's dolphin) averaged 128 HOCs, whereas pinnipeds (California sea lion and Pacific harbor seal) averaged 47 HOCs. We suspect this disparity can be attributed to differences in life history, foraging strategies, and/or enzyme-mediated metabolism. Our results support proposing (1) the long- and short-beaked common dolphin as apex marine predator sentinels for future and retrospective biomonitoring of the SCB ecosystem and (2) the use of non-targeted contaminant analyses to identify and prioritize emerging contaminants. The use of a sentinel marine species together with the non-targeted analytical approach will enable a proactive approach to environmental contaminant monitoring.

CITATION

Cossaboon, J.M., E. Hoh, S.J. Chivers, D.W. Weller, K. Danil, K.A. Maruya, N.G. Dodder. 2019. Apex marine predators and ocean health: Proactive screening of halogenated organic contaminants reveals ecosystem indicator species. *Chemosphere* 221:656-644.

SCCWRP Journal Article #1077
Full text available by request: pubrequest@sccwrp.org

Persistent organic pollutants and mercury in genetically identified inner estuary Bottlenose Dolphin (*Tursiops truncatus*) residents of the Guayaquil Gulf, Ecuador: Ecotoxicological science in support of pollutant management and cetacean conservation

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[5]*Georgia Aquarium, Atlanta, GA*
[6]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[7]*Department of Biological Sciences, DePaul University, Chicago, IL*
[8]*South Carolina Aquarium, Charleston, SC*
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Abstract

The bottlenose dolphin is one of the most common cetaceans found in the coastal waters, estuaries, and mangroves of Ecuador. However, its population size is gradually declining in the Gulf of Guayaquil, and anthropogenic factors including habitat degradation, uncontrolled dolphin watching, dredging activities, increasing maritime traffic, underwater noise, bycatch, and marine pollution have been implicated in their decline. Very little is known about contamination by persistent organic pollutants (POPs) and mercury in bottlenose dolphins from the Pacific coast of South America. To address this research gap, the first assessment of total mercury (THg) and POPs, including polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), and polybrominated diphenyl ethers (PBDEs), in free-ranging bottlenose dolphins in mangroves (El Morro Mangrove Wildlife Refuge) of the Gulf of Guayaquil, was conducted in Ecuador in 2018. Dolphin samples (i.e., skin and blubber; n = 9), were obtained using dart biopsy field methods for contaminant analysis. POP concentrations ranged from 0.56 to 13.0 mg/kg in lipid weight, while THg ranged from 1.92 to 3.63 mg/kg in dry weight. The predominant POPs were OCPs (50% of ΣPOP), followed by PCBs (46%) and PBDEs (6.0%); particularly, p,p 0 -DDE, the main DDT metabolite and a potent antiandrogenic, accounting for 42% of ΣPOP, ranging from 0.12 to ~7.0 mg/kg lw, followed by PCB 153 (8.0%) and PCB 180 (5.0%). PBDE 47 accounted for 2.0% of ΣPOP. While the POP concentrations are lower than those found in dolphins from many other regions of the world, some of the THg concentrations are within the concentration range found in dolphins from the southeastern coast of the United States. The ecotoxicological risk assessment showed that some of the sampled dolphins are exposed to immunotoxic and endocrine disruption effects by POPs and mercury. The low genetic diversity of this distinctive dolphin population, likely exhibiting genetic isolation and a unique evolutionary heritage, could be lost if the population continues to decline in the face of anthropogenic threats, including chemical pollution. Our finding shows that bottlenose dolphins in coastal Ecuador are exposed to environmental contaminants and can be used as sentinel species for ecosystem health to monitor pollution in the region and to support ecotoxicological risk assessment and regional pollutant management.

Citation

Alava, J.J., P. Calle, A. Tirape, G. Biedenbach, O.A. Cadena, K. Maruya, W. Lao, W. Aguirre, P.J. Jimenez, G.A. Dominguez, G.D. Bossart, P.A. Fair. 2020. Persistent Organic Pollutants and Mercury in Genetically Identified Inner Estuary Bottlenose Dolphin (*Tursiops truncatus*) Residents of the Guayaquil Gulf, Ecuador: Ecotoxicological Science in Support of Pollutant Management and Cetacean Conservation. *Frontiers in Marine Science* DOI:10.3389/fmars.2020.00122.

SCCWRP Journal Article #1118
Full text available online: www.sccwrp.org/publications

Species-specific characteristics influence contaminant accumulation trajectories and signatures across ontogeny in three pelagic shark species

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Abstract

Factors influencing organic contaminant accumulation in sharks, especially across ontogeny, are not well-known. Contaminant concentrations were measured in three species of sharks (Blue, Shortfin Mako, and Common Thresher) across a range of size classes (neonatal to adult) that vary in their ecological and physiological characteristics. Empirical data was compared to a theoretical framework that predicted the shape of lifetime accumulation curves. We found that a one-size-fits-all accumulation model was not appropriate as species-specific characteristics had a significant effect on contaminant accumulation trajectories. Maternal offloading likely has an important effect on determining neonatal shark contaminant starting points, and trophic ecology and physiology may interact to affect the shape of species' contaminant accumulation curves. Makos were found to have the highest accumulation potential and Blues the lowest, with Threshers being intermediate in accumulation potential. Changes in species' ecology and/or physiology were also reflected in contaminant signature changes over ontogeny. If contaminant concentrations are to be used as a proxy for risk,

species-specific characteristics need to be taken into account when estimating contaminant exposure and its potential negative effects on shark health and human consumption safety.

CITATION

Lyon, K., D. Kacev, A. Preti, D.J. Gillett, H. Dwar, S. Kohin. 2019. Species-Specific Characteristics Influence Contaminant Accumulation Trajectories and Signatures Across Ontogeny in Three Pelagic Shark Species. *Environmental Science & Technology* DOI:10.1021/acs.est.8b07355.

SCCWRP Journal Article #1079
Full text available by request: pubrequest@sccwrp.org

Evaluating analytical methods for detecting unknown chemicals in recycled water

Keith A. Maruya[1], Charles S. Wong[1]

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

CITATION

Maruya, K., C.S. Wong. 2020. Evaluating Analytical Methods for Detecting Unknown Chemicals in Recycled Water. Technical Report 1164. Water Research Foundation. Alexandria, VA.

SCCWRP Technical Report #1164
Full text available online: www.sccwrp.org/publications

Status of legislation and regulatory drivers for microplastics in California

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[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[2]*California State Water Resources Board, Sacramento, CA*

CITATION

Martindale, S., S.B. Weisberg, S. Coffin. 2020. Status of Legislation and Regulatory Drivers for Microplastics in California. Technical Report 1133. Horiba. Kyoto, Japan.

SCCWRP Technical Report #1133
Full text available online: www.sccwrp.org/publications

Occurrence and bioaccumulation of dissolved organochlorines in San Diego Bay

Steven M. Bay[1], Ashley N. Parks[1]

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

CITATION

Bay, S.M., A.N. Parks. 2020. Occurrence and Bioaccumulation of Dissolved Organochlorines in San Diego Bay. Technical Report 1109. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1109
Full text available online: www.sccwrp.org/publications

Study examines how to monitor COVID-19 in wastewater

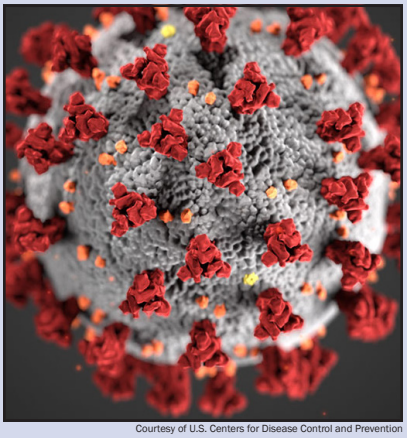
A national research team that includes SCCWRP has begun working to build the tools and infrastructure necessary to monitor wastewater streams for the prevalence of COVID-19 infections in communities.

The project, launched at the start of the pandemic in 2020 and led by researchers at the University of Michigan and Stanford University, aims to build management capacity to routinely measure the levels of virus entering wastewater treatment plants, then correlate the data to levels of COVID-19 infections in local populations.

Wastewater streams have the potential to offer more comprehensive, accurate insights about community infection rates than targeted testing, which so far has been centered primarily around individuals with illness symptoms.

To support the ongoing project, SCCWRP in 2020 worked with its wastewater management member agencies and other treatment plant operators to collect hundreds of samples.

SCCWRP also began investigating potential sources of variability in how the COVID-19 virus in wastewater is collected, preserved and quantified – insights that can help improve the accuracy, repeatability and comparability of different measurement methods and variations of methods.



Courtesy of U.S. Centers for Disease Control and Prevention

The SARS-CoV-2 virus, pictured in this artist rendering, is prevalent in wastewater streams entering treatment plants. At the start of the COVID-19 pandemic, SCCWRP joined a national study investigating how wastewater influent could be used to monitor the prevalence of COVID-19 infections in communities.

Researchers hope to design a wastewater surveillance system that can provide an early-warning indicator of increases in COVID-19 community infection rates, providing critical lead time for public health officials.

Fecal contamination study shows sewers have unique microbial characteristics

SCCWRP and its member agencies have shown in an initial proof-of-concept study that sanitary sewer systems have unique microbial characteristics that could help water-quality managers track the origins of human fecal contamination in urban waterways.

The study, launched in 2019, examined whether the microbial community that lives inside sanitary sewer pipes is unique to sanitary sewer pipes.

Initial results showed that the microbial community coating the inside of the sewer pipes – known as biofilm – has a different DNA-based community profile from the microbial community that lives inside storm drain systems.

The finding provides early evidence that researchers may be able to distinguish aquatic fecal contamination that originated in sewers from fecal contamination that originated from other sources.

Study probes scientific basis for shellfish water-quality standard

SCCWRP and its partners have begun working to evaluate whether a water-quality standard designed to protect the health of people who consume shellfish from Newport Bay in Orange County has been appropriately set – a response to a looming regulatory compliance deadline for recreational shellfishing.

The multi-year study, launched in 2019, is investigating whether California's existing standard for permissible bacterial levels in the water correlates to potentially unsafe levels of pathogens in bivalve shellfish harvested from Newport Bay. Researchers and water-quality managers developed the study in response to a looming bacterial TMDL (total maximum daily load) regulatory deadline in Newport Bay that mandates compliance with the statewide recreational shellfish water-quality standard by 2022.

The standard was set a century ago and has not been validated using local shellfish data. Bivalve shellfish such as mussels and oysters are filter feeders that can take up bacteria and viruses from the water column, potentially concentrating them in their tissues.

A SCCWRP field crew tends to Pacific oysters that were deployed in cages at multiple sites around Orange County's Newport Bay over a six-week period. The study investigated whether California's existing standard for bacterial levels in the water correlates to potentially unsafe levels of pathogens in Newport Bay bivalve shellfish.

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Metagenomics of wastewater influent from Southern California wastewater treatment facilities in the era of COVID-19

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

ABSTRACT

Sequencing wastewater may be useful for detecting pathogens and assaying microbial water quality. We concentrated, extracted, and sequenced nucleic acids from 17 composite influent wastewater samples spanning seven southern California wastewater treatment facilities in May 2020. Bacteria were the most proportionally abundant taxonomic group present, followed by viruses and archaea.

CITATION

Rothman, J.A., T.B. Loveless, M.L. Griffith, J.A. Steele, J.F. Griffith, K.L. Whiteson. 2020. Metagenomics of Wastewater Influent from Southern California Wastewater Treatment Facilities in the Era of COVID-19. *Microbiology Resource Announcements* 9.

SCCWRP Journal Article #1161
Full text available online: www.sccwrp.org/publications

The challenges of microbial source tracking at urban beaches for Quantitative Microbial Risk Assessment (QMRA)

Amity G. Zimmer-Faust[1], Joshua Steele[1], John F. Griffith[1], Ken Schiff[1]

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ABSTRACT

Urban beaches are frequently impacted from multiple sources of fecal contamination. This along with high beach usage underscores the importance of appropriate management that protects swimmer health. The USEPA has enabled the use of QMRA as a tool for quantifying swimmer health risk and setting site-specific water quality objectives. This study illustrates the challenges associated with human and non-human source identification and how these challenges influence the decision of whether QMRA at typical urban beaches for water quality management is appropriate. In this study, a similar and correlated spatial relationship with elevated Enterococcus and avian-specific markers was observed, suggesting shorebirds as a primary source of FIB. However, human- associated markers were also detected frequently but at low concentrations. Ultimately, a QMRA was not con-ducted because pathogen loading from potential human sources could not be confidently quantified, having consequences for health risk in receiving waters where recreational contact occurs.

CITATION

Zimmer-Faust, A.G., J.A. Steele, J.F. Griffith, K.C. Schiff. 2020. The challenges of microbial source tracking at urban beaches for Quantitative Microbial Risk Assessment (QMRA). *Marine Pollution Bulletin* DOI:10.1016/j.marpolbul.2020.111546.9.

SCCWRP Journal Article #1175
Full text available by request: pubrequest@sccwrp.org

Whole-genome sequencing of four *Campylobacter* strains isolated from gull excreta collected from Hobie Beach (Oxnard, CA, USA)

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

ABSTRACT

Campylobacter spp. are commensal organisms in avian species and are one of the leading causes of bacterial foodborne human diarrheal disease worldwide. We report the draft genome sequences of *Campylobacter volucris*, *C. lari*, and *C. jejuni* strains isolated from California gull (*Larus californicus*) excreta collected from a California beach.

CITATION

Gomez-Alvarez, V., N.J. Ashbolt, J.F. Griffith, J.S. Domingo, J. Lu. 2019. Whole-Genome Sequencing of Four Campylobacter Strains Isolated from Gull Excreta Collected from Hobie Beach (Oxnard, CA, USA). *Microbiology Resource Announcements* 8:1-3.

SCCWRP Journal Article #1101
Full text available online: www.sccwrp.org/publications

Large-scale implementation of standardized quantitative real-time PCR fecal source identification procedures in the Tillamook Bay watershed

Xiang Li[1], Mano Sivaganesan[2], Catherine A. Kelty[2], Amity Zimmer-Faust[3], Pat Clinton[4], Jay R. Reichman[5], York Johnson[6], William Matthews[7], Stephanie Bailey[8], Orin C. Shanks[2]

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[3]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[4]*U.S. Environmental Protection Agency, Office of Research and Development, Newport, OR*
[5]*U.S. Environmental Protection Agency, Office of Research and Development, Corvallis, OR*
[6]*Oregon Department of Environmental Quality & Tillamook Estuaries Partnership, Garibaldi, OR*
[7]*Oregon Department of Agriculture, Salem, OR*
[8]*U.S. Environmental Protection Agency, Region 10 Manchester Laboratory, Port Orchard, WA*

ABSTRACT

Fecal pollution management remains one of the biggest challenges for water quality authorities worldwide. Advanced fecal pollution source identification technologies are now available that can provide quantitative information from many animal groups. As public interest in these methodologies grows, it is vital to use standardized procedures with clearly defined data acceptance metrics and conduct field studies demonstrating the use of these techniques to help resolve real-world water quality challenges. Here we apply recently standardized human-associated qPCR methods with custom data acceptance metrics (HF183/ BacR287 and HumM2), along with established procedures for ruminant (Rum2Bac), cattle (CowM2 and CowM3), canine (DG3 and DG37), and avian (GFD) fecal pollution sources to (i) demonstrate the feasibility of implementing standardized qPCR procedures in a largescale field study, and (ii) characterize trends in fecal pollution sources in the research area. A total of 602 water samples were collected over a one-year period at 29 sites along the Trask, Kilchis, and Tillamook rivers and tributaries in the Tillamook Bay Watershed (OR, USA). Host-associated qPCR results were combined with high-resolution geographic information system (GIS) land use and general indicator bacteria (*E. coli*) measurements to elucidate water quality fecal pollution trends. Results demonstrate the feasibility of implementing standardized fecal source identification qPCR methods with established data acceptance metrics in a large-scale field study leading to new investigative leads suggesting that elevated *E. coli* levels may be linked to specific pollution sources and land use activities in the Tillamook Bay Watershed.

CITATION

Li, X., M. Sivaganesan, C.A. Kelty, P. Clinton, J.R. Reichman, Y. Johnson, W. Matthews, S. Bailey, O.C. Shanks, A.G. Zimmer-Faust. 2019. Large-scale implementation of standardized quantitative real-time PCR fecal source identification procedures in the Tillamook Bay Watershed. *PLoS One* DOI:10.1371/journal.pone.0216827.

SCCWRP Journal Article #1102
Full text available online: www.sccwrp.org/publications

Inner Cabrillo Beach microbial source tracking and Quantitative Microbial Risk Assessment (QMRA)

Kenneth Schiff[1], John Griffith[1], Joshua Steele[1], Amy Zimmer-Faust[1], Jeffrey Soller[2]

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[2]*Soller Environmental, LLC*

CITATION

Schiff, K.C., J.F. Griffith, J.A. Steele, A.G. Zimmer-Faust, J.A. Soller. 2019. Inner Cabrillo Beach Microbial Source Tracking and Quantitative Microbial Risk Assessment (QMRA). Technical Report 1068. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1068
Full text available online: www.sccwrp.org/publications

Los Coches Creek microbial source tracking study

Joshua Steele[1], Darcy Ebentier McCargar[2], Amy Zimmer-Faust[1], John Griffith[1], and Kenneth Schiff[1]

[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*
[2]*Wood Environment and Infrastructure Solutions, San Diego, CA*

CITATION

Steele, J.A., D. Ebentier, A.G. Zimmer-Faust, J.F. Griffith, K.C. Schiff. 2019. Los Coches Creek Microbial Source Tracking Study. Technical Report 1087. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1087
Full text available online: www.sccwrp.org/publications

Tool developed to assess BMP performance effectiveness

SCCWRP has developed an integrated, web-based tool intended to help California's stormwater management community assess the effectiveness of vegetated swales, permeable pavement and other BMPs (best management practices) in removing contaminants during wet weather.

The California BMP Effectiveness Calculator, unveiled in 2019, provides a wealth of California-specific data on the performance effectiveness of a common type of engineered BMP solution known as a flow-through BMP. With a flow-through BMP, contaminants are treated and removed as stormwater passes through.

California stormwater managers can use the California BMP Effectiveness Calculator to assess how well five types of flow-through BMPs perform in treating more than a dozen types of stormwater contaminants, from dissolved copper to nitrate.

The web-based calculator automatically estimates the concentration of the effluent, based on incoming contaminant concentration in the stormwater.

The calculator also automatically calculates the level of certainty associated with estimates of BMP performance effectiveness. This type of analysis is a critical component of modeling the effectiveness of BMPs that have yet to be implemented in a watershed.

A bioretention system that abuts the shoreline in Long Beach filters and removes stormwater contaminants, helping to protect beach water quality. Researchers have developed a new tool for predicting stormwater BMP effectiveness that is available online at https://sccwrp.shinyapps.io/bmp_eval.

Strategy developed for how to quantify stormwater capture statewide

SCCWRP and its partners have developed a six-part strategy that California could use to begin tracking how much stormwater is being captured statewide, part of an ongoing effort to improve water use and reuse practices across drought-prone California.

The strategy, published in 2020, outlines a series of technical approaches that the State Water Resources Control Board could implement to quantify stormwater capture across six distinct components of water resources infrastructure, from stormwater BMPs (best management practices) to inflows at wastewater treatment plants.

The report's authors examined the complexity, accuracy and level of effort associated with implementing various quantification methods. The State Water Board intends to use the report as it works to build capacity to track the total volume of stormwater being captured statewide.

SMC develops roadmap to improve runoff water quality

The Southern California Stormwater Monitoring Coalition (SMC) has unveiled a comprehensive, multi-faceted research agenda that lays out a vision and roadmap for how the region's stormwater management community will collaborate to improve runoff water quality over the next five years.

The 2019-2024 Research Agenda spans multiple areas of stormwater science, from optimizing the performance of stormwater BMPs (best management practices) to modernizing data sharing and analysis capabilities. The SMC's governing board in 2020 greenlit an initial subset of projects on the list.

Developed by a 10-member advisory panel, the Research Agenda consists of 24 priority projects.

SCCWRP helped conceptualize and develop the research agenda, and the document will play a key role in shaping SCCWRP's own long-term research directions.

Courtesy of Los Angeles County Department of Public Works

Runoff flows into a bioswale in Marina del Rey in Los Angeles County. Southern California stormwater managers have developed a five-year research agenda that will work toward optimizing the performance of bioswales and other stormwater control measures.

SCCWRP previously facilitated the development and successful implementation of two prior research aendas for the SMC.

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Conventional and amended bioretention soil media for targeted pollutant treatment: A critical review to guide the state of the practice

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Abstract

Bioretention systems are widely used green infrastructure elements that utilize engineered bioretention soil media (BSM) for stormwater capture and treatment. Conventional bioretention soil media, which typically consists of sand, sandy loam, loamy sand or topsoil amended with compost, has limited capacity to remove and may leach some stormwater pollutants. Alternative engineered amendments, both organic and inorganic, have been tested to supplement BSM. Yet, municipalities and regulatory agencies have been slow to adopt these alternative amendments into their design specifications, partly because of a lack of clear guidance on how to select the right amendment to treat a target stormwater contaminant under highly variable climatic conditions. This article aims to provide that guidance by: (1) summarizing the current design BSM specifications adopted by jurisdictions worldwide, (2) comparing the performance of conventional and amended BSM, (3) highlighting advantages and limitations of BSM amendments, and (4) identifying challenges for implementing amendments in field conditions. The analysis not only informs the research community of the barriers faced by stormwater managers in implementing BSM amendments but also provides guidelines for their adoption by interested agencies to comply with existing regulations and meet design needs. This feedback loop could catalyze further innovation in the development of sustainable stormwater treatment technologies.

Citation

Tirpak, R.A., N. Afrooz, R.J. Winston, R. Valenca, K.C. Schiff, S.K. Mohanty. 2020. Conventional and amended bioretention soil media for targeted pollutant treatment: A critical review to guide the state of the practice. *Water Research* DOI:10.1016/j.watres.2020.1166480.

SCCWRP Journal Article #1160
Full text available by request: pubrequest@sccwrp.org

Design aspects and plant species affect pollutant removal in Southern California stormwater biofilters

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Abstract

We conducted a column study to better understand the relative effects of plants, design elements, and operating conditions on pollutant removal in stormwater biofilters in southern California under local conditions. We planted five southern California native species (*Baccharis pilularis, Carex praegracilis, Juncus patens, Leymus condensatus, and Muhlenbergia rigens*) in experimental biofilter columns fitted with a saturated zone and evaluated pollutant removal during weekly dosing and following a 52-day dry period. Columns planted with *C. Praegracilis* and *J. patens* were also evaluated under conditions of fortnightly dosing and without the presence of a saturated zone. During weekly dosing, planted columns had a total nitrogen removal efficiency of 46% on average whereas removal was 8% in unplanted columns. *B. pilularis* and *M. rigens* performed better than other species at nitrogen removal. The presence of a saturated zone improved nitrogen removal and metal removal, but only before the52-day dry period. With a few exceptions, local best management practice effluent concentrations limits were exceeded but performed similarly to existing southern California biofilters. Nitrogen removal decreased slightly under a fortnightly dosing frequency, which better represented rainfall event frequency in Los Angeles when compared to weekly dosing.

Citation

Winfrey, B.K., M. Ho, W. Wang, Y.J. Li, R.F. Ambrose. 2020. Design aspects and plant species affect pollutant removal in Southern California stormwater biofilters. *Blue-Green Systems* DOI:10.2166/bgs.2020.012.

SCCWRP Journal Article #1180
Full text available online: www.sccwrp.org/publications

Bioretention planter performance measured by lag and capture

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Abstract

Bioretention flow-through planters manage stormwater with smaller space requirements or structural constraints associated with other forms of green infrastructure. This

project monitored the hydrology of four bioretention planters at Stevens Institute of Technology to evaluate the system's ability to delay runoff and fully capture small rain events. The water depth in the outflow and the volumetric water content near the inflow were measured continuously over 15 months. Rainfall characteristics were documented from an on-site rain gauge. This monitoring determined the time from the start of a rain event to the onset of outflow from each planter, which was defined as the lag. The initial moisture deficit (difference between pre-event volumetric water content and maximum measured volumetric water content), approximate runoff volume, and approximate runoff volume in the first half hour were analysed to determine their effect on runoff capture and lag. During the monitoring period, 38% of observations did not produce measurable outflow. Logistic regression determined that the initial moisture deficit and approximate runoff volume were statistically significant in contributing to a fully captured storm. Despite the large hydraulic loading rate and concrete bottom, the planters demonstrate effective discharge lag, ranging from 5 to 1,841 min with a median of 77.5 min. Volumetric water content of the media and inlet runoff volume in the first half hour were significant in modelling the lag duration. These results represent a combination of controllable and uncontrollable aspects of green infrastructure: media design and rainfall.

CITATION

Nissen, K.A., M. Borst, E. Fassman-Beck. 2020. Bioretention planter performance measured by lag and capture. *Hydrological Processes* DOI:10.1002/hyp.13927.

SCCWRP Journal Article #1152
Full text available by request: pubrequest@sccwrp.org

Stormwater green infrastructures retain high concentrations of TiO_2 engineered (nano)-particles

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ABSTRACT

Stormwater conveys natural and engineered (nano)-particles, like any other pollutants, from urban areas to water resources. Thus, the use of stormwater green infrastructures (SGI), which infiltrate and treat stormwater, can potentially limit the spread of engineered (nano)-particles in the environment. However, the concentration of engineered (nano)- particles in soil or biofilter media used in SGI has not been measured due to difficulties in distinguishing natural vs. engineered (nano)-particles. This study reports, for the first time, the concentration and size distribution of TiO_2 engineered (nano)-particles in soils collected from SGI. The concentrations of TiO_2 engineered (nano)-particles were determined by mass balance calculations based on shifts in elemental concentration ratios, i.e., Ti to Nb, Ti to Ta, and Ti to Al in SGI soils relative to natural background elemental ratios. The concentrations of TiO_2 engineered (nano)-particles in SGI soils varied between 550±13 and 1800±200 mg kg^{-1}. A small fraction of TiO_2 engineered (nano)-particles could be extracted by ultrapure water (UPW) and $Na_4P_2O_7$; however, the concentration of TiO_2 engineered (nano)-particles was higher in the $Na_4P_2O_7$-extracted suspensions than in UPW-extracted suspensions. The concentration of TiO_2 in the nanosize range increased with the increase in extractant ($Na_4P_2O_7$) volume to soil mass ratio due to the increased disaggregation of soil heteroaggregates. The size distribution of TiO_2 engineered (nano)-particles in the <450 nm $Na_4P_2O_7$-extracted suspension from one of the SGI soils was determined by asymmetrical flow-field flow fractionation coupled to inductively coupled plasma-mass spectrometer, and was found to vary in the range of 25−200 nm with a modal size of 50 nm. These results demonstrated that the increase in the Ti to natural tracers (e.g., Nb, Ta, and Al) elemental ratios in the SGI soil relative to bulk soil can be used to estimate the concentration of TiO_2 engineered (nano)-particles in SGI.

CITATION

Baalousha, M., J. Wang, M. Nabi, F. Loosli, R. Valenca, S.K. Mohanty, N. Afrooz, E. Cantando, N. Aich. 2020. Stormwater green infrastructures retain high concentrations of TiO_2 engineered (nano)-particles. *Journal of Hazardous Materials* DOI:10.1016/j.jhazmat.2020.122335.

SCCWRP Journal Article #1113
Full text available by request: pubrequest@sccwrp.org

Improving effective impervious estimates to inform stormwater management

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ABSTRACT

Sizing stormwater runoff control facilities and their performance relies on the amount of runoff generated from impervious cover in the watershed. Total impervious area (TIA) often overestimates unit runoff values because it fails to account for intervening pervious surfaces which can reduce effective impervious area (EIA) below the TIA. While EIA is a better estimator for designing stormwater control facilities, direct measurement of EIA can be limited to small catchments as the process is rigorous and time intensive. This paper develops an EIA-TIA regression relationship with a single parameter TIA for semi-arid Southern California. TIA of seven

watersheds of the region is calculated from 30 m resolution National Land Cover Dataset and EIA is indirectly measured from observed rainfall and runoff data from 2005 to 2007 in study watersheds using three methods – (1) Ordinary Least Square (OLS), (2) Modified Ordinary Least Square (MOLS) and (3) Weighted Least Square (WLS) methods. Results show that a linear relationship between EIA derived from WLS method and estimated watershed TIA meet the sensitivity test requirement and have highest R2 value. This empirical EIA-TIA relationship is valid for watersheds with TIA greater than 2.56% and estimated EIAs for the study watersheds are between 20 and 50% lower than the TIAs. Using EIA instead of TIA can results in reduced runoff volume and the associated design size of stormwater control devices. This empirical relationship can be applied to other semi-arid watersheds with similar size, land use and other geomorphic characteristics.

Citation

Sultana, R., M. Mroczek, A. Sengupta, S. Dallman, E.D. Stein. 2020. Improving Effective Impervious Estimates to Inform Stormwater Management. *Water Resources Management* DOI:10.1007/s11269-019-02474-7.

SCCWRP Journal Article #1106
Full text available by request: pubrequest@sccwrp.org

Evaluating potential methods to quantify stormwater capture

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Citation

Fassman-Beck, E., K.C. Schiff, D. Apt. 2020. Evaluating Potential Methods to Quantify Stormwater Capture. Technical Report 1116. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1116
Full text available online: www.sccwrp.org/publications

BMP performance monitoring data compilation to support reasonable assurance analysis

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[2]*San Francisco Estuary Institute, San Francisco, CA*

Citation

Afrooz, N., M. Beck, T. Hale, L. McKee, K.C. Schiff. 2019. BMP Performance Monitoring Data Compilation to Support Reasonable Assurance Analysis. Technical Report 1081. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1081
Full text available online: www.sccwrp.org/publications

Southern California Stormwater Monitoring Coalition five-year research agenda 2019-2024

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[9]*San Francisco Estuary Institute, Richmond, CA*

Citation

Ashby, K., A. Davis, G. Gearheart, J. Harwood, T. Hogue, D. Kleis, S. Luce, P. Ode, D. Senn. 2020. Southern California Stormwater Monitoring Coalition Five-Year Research Agenda 2019-2024. Technical Report 1126. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1126
Full text available online: www.sccwrp.org/publications

Bight '18 completes its first three Sediment Quality studies

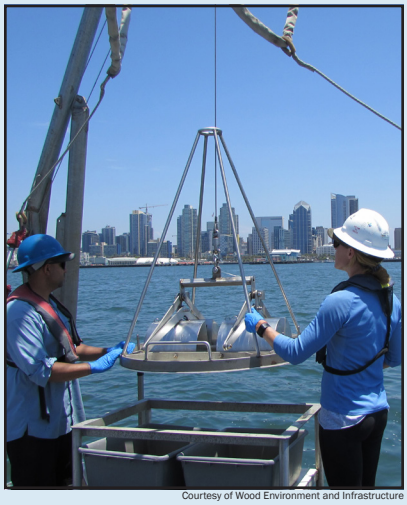
The Southern California Bight 2018 Regional Monitoring Program has completed its first three Sediment Quality assessment reports examining how coastal seafloor sediment has been impacted by contamination.

The three 2020 reports – Sediment Toxicity, Sediment Chemistry and Bioaccumulation in Sportfish – provide multiple lines of evidence for assessing sediment quality impacts across Southern California's coastal ocean:

» Bight '18 Sediment Toxicity found that sediment toxicity remained low overall across the coastal ocean. Although sediment toxicity declined or remained the same in some habitats compared to Bight '13 toxicity data, the study found that toxicity was higher in marinas and estuaries.

» Bight '18 Sediment Chemistry found that 79% of sediment was considered to produce minimal to low chemical contamination exposure levels – a finding that has remained relatively consistent over the past 15 years. Only 3% of sediment Bight-wide was in the worst, or high exposure, category.

» Bight '18 Contaminant Bioaccumulation in Edible Sport Fish Tissue found that contamination levels in the tissues of commonly caught Southern California sportfish were within "safe to eat" thresholds for consumption at least once a week. None of the average contamination levels reported in the sportfish would place them in the most restrictive "Do not consume" consumption advisory threshold, as defined by California's Office of Environmental Health Hazard Assessment (OEHHA).



Courtesy of Wood Environment and Infrastructure

A field crew lowers a sediment grab sampler into San Diego Bay during field sampling for the Southern California Bight 2018 Regional Monitoring Program. Three Bight '18 Sediment Quality studies were published in 2020.

First decade of SMC stream monitoring offers insights into regional condition over time

The Southern California Stormwater Monitoring Coalition (SMC) has completed an analysis of the first decade of its regional stream monitoring program that found that the biological integrity of most perennially flowing streams across coastal Southern California has generally been stable over a decade-long span that ended in 2018.

The SMC Regional Watershed Monitoring Program analysis, co-authored by SCCWRP and published in 2020, found that about one in four stream-miles across the South Coast region was considered to have biological communities that were "likely intact" – the highest of four possible stream condition categories. The other three-quarters of the region's stream-miles were considered to have possibly, likely or very likely altered biological communities.

The SMC conducts bioassessment sampling annually to estimate the overall health of the region's streams.

Bight '18 study documents domoic acid across coastal ocean seafloor

The Southern California Bight 2018 Regional Monitoring Program has completed a study examining how a toxin produced by a certain ubiquitous type of marine algae can settle and persist in seafloor sediment, and then accumulate in the tissues of small, sediment-dwelling organisms exposed to the toxin.

The study, completed in 2020, detected domoic acid in sediment across 54% of the Southern California Bight continental shelf. Domoic acid also was consistently found throughout the year in the organisms that live in and on sediment – known as benthic infauna – even at times of the year when domoic acid isn't being produced, and even in places where the toxin could not be detected in the surrounding sediment.

Domoic acid is produced by *Pseudo-nitzschia*, the most common type of harmful algal bloom (HAB) found in Southern California's coastal ocean. The toxin can strand and kill marine mammals, and sicken humans who consume contaminated seafood.

The Southern California Bight 2018 Regional Monitoring Program examined whether a marine toxin known as domoic acid was found in the tissues of small sediment-dwelling organisms, above. These biological communities could be exposed to domoic acid that has settled and persisted in seafloor sediment.

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Southern California Bight

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Abstract

The Southern California Bight (SCB) coastal environment is a unique ecological resource. Extending >600 km from Point Conception (United States) to Punta Colonet (Mexico), the SCB is a dynamic subtemperate region where the cold, southward-flowing California Current mixes with the warm, northward-flowing California Countercurrent. Large variations of interannual average ocean temperature occur during El Niño and La Niña, ranging >10 °C in surface waters of the SCB. The SCB borderland has relatively complicated geography. Located at the margin of the North American and Pacific plates, this active tectonic region has a narrow continental shelf averaging 5 km width. At the continental shelf break in roughly 200 m depth, continental slopes plunge to 1000 m depth forming deepwater basins, only to rise again in a chain of nine offshore islands. The SCB's heterogenous physical settings and dynamic ocean currents provide habitat for a large diversity of flora and fauna. Cumulative across all habitats, >350 fish and 5000 invertebrate species are endemic to the SCB, including over one dozen threatened or endangered marine mammals and seabirds. Biomes are generally spread across latitude which varies with ocean temperature—warmer species to the south and colder species to the north—and depth. Population recruitment and senescence are often coincident with El Niño when warm water species dominate and La Niña when cold water species dominate. Approximately 85% of the species in the SCB are at the extreme northern or southern end of their range. The SCB has several ecologically critical habitats. One characteristic ecosystem in the SCB is subtidal rocky reefs dominated by the giant kelp Macrocystis. These "kelp forests" are estimated to be among the most productive on earth, rivaling coral reefs. The SCB has 331 coastal wetlands, but only 23 are >100 HA and most are very small and fractured (<1 HA). The majority (57%) of the SCB coastal wetland area has been lost to coastal development since the turn of the 19th century. The remaining coastal wetlands are critical habitat providing fish nurseries and overwintering stops for birds along the Pacific Flyway.

Citation

Schiff, K.C., K. McLaughlin, S.L. Moore, Y. Cao. 2019. Southern California Bight. in: C. Sheppard (ed.), *World Seas: An Environmental Evaluation* pp. 465-482. Academic Press. London, UK.

SCCWRP Book Chapter #1051
Full text available online: www.sccwrp.org/publications

Key to Combfishes and Greenlings (Families *Zaniolepididae* and *Hexagrammidae*)

Dario Diehl[1]

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Citation

Diehl, D.W. 2020. Key to Combfishes and Greenlings (Families *Zaniolepididae* and *Hexagrammidae*). in: M.S. Love, J.K. Passarelli (eds.), *Miller and Lea's Guide to Coastal Marine Fishes of California* pp. 175-178. UC Agriculture and Natural Resources. Davis, CA.

SCCWRP Book Chapter #1167
Full text available by request: pubrequest@sccwrp.org

Key to the Jacks (Family *Carangidae*)

Dario Diehl[1]

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Citation

Diehl, D.W. 2020. Key to the Jacks (Family *Carangidae*). in: M.S. Love, J.K. Passarelli (eds.), *Miller and Lea's Guide to Coastal Marine Fishes of California* pp. 235-242. UC Agriculture and Natural Resources. Davis, CA.

SCCWRP Book Chapter #1168
Full text available by request: pubrequest@sccwrp.org

Key to Driftfishes (Family *Nomeidae*)

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

Citation

Love, M.S., D.W. Diehl. 2020. Key to Driftfishes (Family *Nomeidae*). in: J.K. Passarelli (ed.), *Miller and Lea's Guide to Coastal Marine Fishes of California* pp. 342. UC Agriculture and Natural Resources. Davis, CA.

SCCWRP Book Chapter #1169
Full text available by request: pubrequest@sccwrp.org

2018-2019 report on the SMC stream survey

Kris Taniguchi-Quan[1], Raphael Mazor[1], Jeff Brown[1], Rebekah Guill[2], Matt Yeager[2], Abigail Suter[2], John Rudolph[3], William Isham[3], Scott Johnson[4]

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Citation

Taniguchi-Quan, K.T., R.D. Mazor, J.S. Brown, R. Guill, M. Yeager, A. Suter, J. Rudolph, W. Isham, S. Johnson. 2020. 2018-2019 Report on the SMC Stream Survey. Technical Report 1127. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1127
Full text available online: www.sccwrp.org/publications

Southern California Bight 2018 Regional Monitoring Program: Volume I. Sediment toxicity

Ashley N. Parks[1], Darrin J. Greenstein[1], Karen McLaughlin[1], and Kenneth Schiff[1]

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CITATION

Parks, A.N., D.J. Greenstein, K. McLaughlin, K.C. Schiff. 2020. Southern California Bight 2018 Regional Monitoring Program: Volume I. Sediment Toxicity. Technical Report 1117. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1117
Full text available online: www.sccwrp.org/publications

Southern California Bight 2018 Regional Monitoring Program: Volume II. Sediment chemistry

Bowen Du[1], Charles S. Wong[1], Karen McLaughlin[1], and Kenneth Schiff[1]

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CITATION

Du, B., C.S. Wong, K. McLaughlin, K.C. Schiff. 2020. Southern California Bight 2018 Regional Monitoring Program: Volume II. Sediment Chemistry. Technical Report 1130. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1130
Full text available online: www.sccwrp.org/publications

Southern California Bight 2018 Regional Monitoring Program: Volume V. Contaminant bioaccumulation in edible sport fish tissue

Karen McLaughlin[1], Kenneth Schiff[1], Bowen Du[1], Jay Davis[2], Autumn Bonnema[3], Gary Ichikawa[3], Billy Jakl[3], and Wesley Heim[3]

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[2]*San Francisco Estuary Institute, Richmond, CA*
[3]*Moss Landing Marine Laboratories, Moss Landing, CA*

CITATION

McLaughlin, K., K.C. Schiff, B. Du, J. Davis, A. Bonnema, G. Ichikawa, B. Jakl, W. Heim. 2020. Southern California Bight 2018 Regional Monitoring Program Volume V: Contaminant Bioaccumulation in Edible Sport Fish Tissue. Technical Report 1155. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1155
Full text available online: www.sccwrp.org/publications

Findings and recommendations of the Expert Review Panel for the Eastern San Joaquin Surface Water Monitoring Program

Kevin Armbrust[1], Jon Costantino[2], John Hunt[3], Charles Menzie[4], Doug Parker[5]

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[2]*Tradesman Advisors, Auburn, CA*
[3]*University of California, Davis, Davis, CA*
[4]*Society of Environmental Toxicology and Chemistry, Pensacola, FL*
[5]*California Institute for Water Resources, University of California, Oakland, CA*

CITATION

Armbrust, K., J. Constantino, J. Hunt, C. Menzie, D. Parker. 2020. Findings and Recommendations of the Expert Review Panel for the Eastern San Joaquin Surface Water Monitoring Program. Technical Report 1153. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1153
Full text available online: www.sccwrp.org/publications

Survey of sediment quality in the Sacramento-San Joaquin Delta

Steven M. Bay[1], Sarah Lowe[2], Karen Gehrts[3]

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[3]*Department of Water Resources, Sacramento, CA*

CITATION

Bay, S.M., S. Lowe, K. Gehrts. 2020. Survey of Sediment Quality in the Sacramento-San Joaquin Delta. Technical Report 686. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #0686
Full text available online: www.sccwrp.org/publications

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Public Policy Institute of California

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Southern California Wetlands Recovery Project

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Dr. **Martha Sutula**, Member, Science Advisory Panel

Surface Water Ambient Monitoring Program

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Dr. **Eric Stein**, Member, Round Table

Dr. **Susanna Theroux**, Member, Bioassessment Workgroup

University of California Marine Managed Areas

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University of California Sea Grant

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University of Southern California Sea Grant

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West Coast Ocean Partnership/West Coast Regional Planning Body

Dr. **Stephen Weisberg**, Co-Chair, West Coast Ocean Data Portal

Local and Project Level

Alfred P. Sloan Foundation

Dr. **John Griffith**, Expert Panel Member, SARS-CoV-2 Sewage Surveillance Program Network

Buccaneer Beach and Loma Alta Creek Microbial Source Identification Study

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CALeDNA Protecting Our River

Dr. **Susanna Theroux**, Member, Technical Advisory Committee

California Department of Fish and Wildlife

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City of Imperial Beach

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Dr. **Eric Stein**, Technical Advisory Committee Member, City of Los Angeles Biodiversity Index Team

Colorado Lagoon Mitigation Banking

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County of Los Angeles Department of Public Works

Dr. **Elizabeth Fassman-Beck**, Technical Advisory Committee Member, Strategic Planning Group LID/Groundwater Study

Dr. **Elizabeth Fassman-Beck**, Technical Advisory Committee Member, Watershed Management Modeling System

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County of San Diego Watershed Protection Program

Dr. **Eric Stein**, Member, Technical Advisory Committee, Regional Water Quality Equivalency Guidance Document

Elkhorn Slough Tidal Wetland Project

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Global Water Research Coalition

Dr. **Alvina Mehinto**, Technical Advisory Committee Member, Effect-Based Monitoring in Water Safety Planning

Industrial Environmental Association of Southern California

Ken Schiff, Member, Technical Advisory Committee on Stormwater Monitoring

Integral Corporation

Dr. **Faycal Kessouri**, Technical Advisory Committee Member, Effects of Offshore Wind Farms on the California Upwelling Ecosystem

James River Proposed Chlorophyll-a Criteria Development

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King County, Washington

Ken Schiff, Member, Water Quality Benefits Evaluation Advisory Committee

Laguna Oceans Foundation

Dr. **Eric Stein**, Chair, Science Advisory Team, Aliso Creek Estuary Restoration

Los Angeles County Department of Public Works

Dr. **Elizabeth Fassman-Beck**, Member, Technical Advisory Group, Groundwater/Low Impact Development Project

Los Angeles River Watershed Monitoring Group

Dr. **Raphael Mazor**, Member, Technical Advisory Group

Los Angeles Freshwater Mussel Restoration Project

Dr. **Raphael Mazor**, Member, Technical Advisory Group

Los Cerritos Wetland Conservation Authority

Dr. **Eric Stein**, Member, Los Cerritos Wetland Restoration Technical Advisory Committee

Louisiana Coastal Protection and Restoration Authority

Dr. **Martha Sutula**, Member, Advisory Panel on Diversions for the Mississippi River and Atchafalaya Basins

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Malibu Lagoon Restoration

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Dr. **Eric Stein**, Member, Southern California Greenprint Advisory Committee

Newport Bay Naturalists and Friends

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Orange County Infrastructure Report Card

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San Diego Climate Science Alliance

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San Diego Wet Weather Bacterial TMDL Compliance Cost-Benefit Analysis

Ken Schiff, Chair, Technical Advisory Committee

San Francisco Bay Nutrient Management Strategy

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Dr. **Martha Sutula**, Member, Science Advisory Team, Tidal Restoration Program

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U.S. Geological Survey

Dr. **Alvina Mehinto**, Scientific Advisor, Columbia Environmental Research Center Sturgeon Gene Expression Project

U.S. Navy Space and Naval Warfare Systems Command

Ken Schiff, Member, Pulsed Stormwater Toxicity Advisory Committee, Upper Santa Ana River Habitat Conservation Plan

Dr. **Eric Stein**, Member, Hydrology Technical Advisory Committee

Vanguard University

Dr. **Jayme Smith**, Member, Science and Pre-Engineering Advisory Council

Water Research Foundation

Dr. **Alvina Mehinto**, Project Advisory Committee Member, Development of Standard Operating Procedures for the Collection, Storage, and Extraction of Aqueous Samples for *In Vitro* Bioanalytical Screening (4828)

Journal Editorships

Applied and Environmental Microbiology

Dr. **John Griffith**, Editorial Board Member

Applied Spectroscopy

Dr. **Stephen Weisberg**, Guest Editor, Microplastics Measurement Methods

Chemosphere

Dr. **Alvina Mehinto**, Editor, Toxicology and Risk Assessment Section

Critical Reviews in Environmental Science and Technology

Dr. **Charles Wong**, Associate Editor

Diversity

Dr. **Nina Bednarsek**, Guest Editor, Effects of Ocean Acidification Across Lower Pelagic Trophic Levels

Elementa: Science of the Anthropocene

Dr. **Martha Sutula**, Associate Editor

Environmental Pollution

Dr. **Charles Wong**, Associate Editor

Environmental Toxicology and Chemistry

Dr. **Bowen Du**, Guest Editor, Non-Targeted Chemical Analysis for Environmental Monitoring

Dr. **Alvina Mehinto**, Editorial Board Member

Environmental Science & Technology Letters

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Freshwater Biology

Dr. **Eric Stein**, Co-Editor, Special Issue on Environmental Flows

Freshwater Science

Dr. **Raphael Mazor**, Associate Editor

Frontiers in Marine Science

Dr. **Nina Bednaršek**, Topic Editor, Acidification and Hypoxia in Marginal Seas

Journal of Sustainable Water in the Built Environment

Dr. **Elizabeth Fassman-Beck**, Lead Guest Editor, Pathogens and Fecal Indicators in Stormwater

Dr. **Joshua Steele**, Guest Editor, Pathogens and Fecal Indicators in Stormwater

Marine Pollution Bulletin

Ken Schiff, Associate Editor

Toxics

Dr. **Alvina Mehinto**, Guest Editor, Agrochemical Impacts on Aquatic Ecosystems

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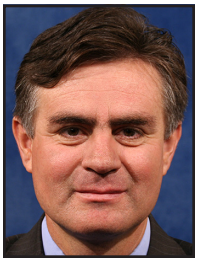
Wastewater Treatment Agencies

City of Los Angeles Bureau of Sanitation



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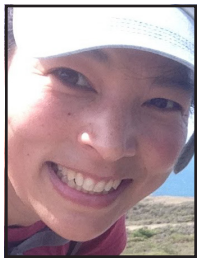

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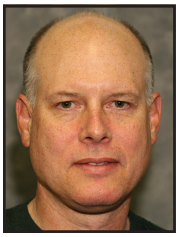

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